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Mathematics and Gender: A General History of Recent Research and Common Perceptions.

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MATHEMATICS AND GENDER:
A GENERAL HISTORY
OF RECENT RESEARCH AND COMMON PERCEPTIONS

A Dissertation

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In memory of my father

Bert Lee Reeves

1914 - 1993

He taught me to believe

in the power of education

and in myself

ACKNOWLEDGMENTS

There are so many people responsible for the creation of something like this that it is impossible to list them all. However, the contributions of some are so significant that they immediately come to mind.

I must begin with my family, my husband and my parents, as well as his parents and my sister and her family. Their continued unwavering support has been crucial to the completion of this project. Thank you for loving me through all of this.

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I also wish to thank all my teachers, both admirable and not, for the inspiration to follow proudly in those harassed and belittled footsteps. I include in this group the members of my dissertation committee, who taught me so much.

I must also acknowledge the comfort and support of many friends, Sondra, Patti and Daniel, Robert, Lynda, John (all of you), Margaret, Susan, Wen-Song, Molly. Thanks for everything -- encouragement, sympathy, ideas, and not knocking or calling when I was writing.

Finally, a general word of thanks to all those who are unnamed, unknown, and unknowable who have touched my life, and therefore this writing, and who will be touched by it.

PREFACE

> History is a discipline of aggregate bias. A history may emphasize social events, or cultural or political or economic or scientific or military or agricultural or artistic or philosophical. It may, if it possesses the luxury of voluminousness or the arrogance of superficiality, attempt to place nearly equal emphasis upon each of the these aspects. . . . If there is anything which the writer has learned . . . it is that the fullness of existence embodies an overwhelmingly intricate balance of defined, ill-defined, undefined, moving, stopping, dancing, falling, singing, coughing, growing, dying, timeless and time-bound molecules -- and the spaces in between. (Robbins, 1971, p. 114)

> *Ostranenie* (Russian): Art as defamiliarization; making familiar perceptions seem strange. . . . The familiarization of the world is an all-too-common phenomenon in an age when you can travel to virtually every major city in every country and stay in the same kind of room that is part of the same hotel chain, eat the same fast food, and watch the same television shows. But the defamiliarization of the world, the renewal of perceptions, is necessary for our mental well-being. (Rheingold, 1988, pp.84-85)

What follows, this dissertation, will tell a story about many things: the development of a technological crisis in popular American consciousness, and an educational answer to it; the continuing evolution of feminism; the proliferation of interest into the problem of "underachievement" of females in mathematics; the struggles of one graduate student to articulate and perhaps understand her own path. This is not just a story; in many deeply personal ways it is my story.

It is difficult to say when my story begins, and where this telling should begin. It could, of course, begin with my birth, or that of my parents. But it could also begin with the "shot heard 'round the world," the crucifixion, or the big bang. Still perhaps a better place to begin this telling is with the first thoughts of Descartes, the fall of Vicksburg, or with the publication of Carson's *Silent Spring* and Friedan's *The Feminine Mystique*.

This story has been difficult to write, both because of its size, that is, the wide-reaching connections hinted at above, and my own involvement and interest in the topic. To tell of my connections to this material, I must tell of my relationship to mathematics and to learning, much of which I learned in my home. Therefore, the stories of my parents, teachers, and peers, are equally part of this story that is only partially my own. Deciding how to present this story that is and is not mine is critical to the nature of meaning that it will spawn.

The writing of this story, this dissertation process, has woven itself into what is written. Though not always explicit in the text, the final form that it now takes is only one of many manifestations that it could have assumed. This seemingly singular writing has been shaped by and has shaped both the author and itself, emerging only in the acts of writing and reading. I have consciously approached the writing of this dissertation over the course of the (few) years since I started graduate school, but gender issues and mathematics learning have interested me since I first became aware of myself as a female and as a lover of mathematics. As a graduate student, these interests were nourished in my coursework, usually separately; that is, mathematics education in some courses and feminist theory in others. This dissertation is the result of my bringing them back together.

I cannot pretend that what follows presents "the truth," in the sense that such documents usually present themselves as replete with truth. That is not, to paraphrase Michel Foucault (1980), to say that truth is absent; this is merely a story that I, in my particularity, have fictioned on the basis of a political reality that makes it true.

Furthermore, I am conscious of attempting to make "familiar perceptions" about gender and mathematics "seem strange." This fiction-which-functions-in-truth (Walkerdine, 1990) raises troubling questions about the implicit assumptions of those perceptions and the consequences of research. This examination of perceptions and research will bring those assumptions to light, and will propose alternative assumptions, perceptions, and research agendas.

This story is not an attempt to provide and prove a seamless theory of the historical development of interest in the mathematical development of women, a *total history*, but a *general history*. A total history is one which "seeks to reconstitute the overall form of a civilization . . . the significance common to all the phenomena of a period, the law that accounts for their cohesion" (Foucault, 1972, p. 9); a general history seeks instead to

> determine what form of relation may be legitimately described between . . . different series; what vertical system they are capable of forming; what interplay of correlation and dominance exists between them; what may be the effect of shifts, different temporalities, and various rehandlings [of them]. (p. 10)

The citations included herein were selected from those that were part of my own education and those that emerged as significant in my reading and rereading of the voluminous literature on gender and mathematics. I cannot pretend that what follows is a comprehensive history of this body of research, that all the questions that interest me in this area have been suggested, or that all of the "great works" have been included. Through the writing, certain themes and authors emerged as significant to the present work and these have been followed. This approach, termed "phenomenological" in the work of Belenky (1986), allowed for some of the presuppositions and frames-of-reference in the literature, as well as in the present work, to display their significance.

This is the story of many, but it is my story, too. It represents only the beginning of my concerns with gender and mathematics and schools. The only place to begin this story is with the teller.

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ABSTRACT

In the last two decades a tremendous volume of research data has been collected about differences between female and male students in mathematics. But although the volume of data has been large, there have been few conscious attempts to understand this data in social, economic, technological, and political terms. This history of academic research on gender differences connects the explosion of academic interest in the 1970s and 1980s with the launch of Sputnik in 1957 and the sense of technological crisis that pervades mathematics education and popular consciousness. The emergence of "Women's Lib" and interest in gender equity in the 1960s and 1970s are also linked to the literature reviewed.

Fundamental to the discourse on gender differences is the notion of equal ability, which is studied through use of variables such as participation, attainment, or achievement. Although no explicit treatment is given to ability in the mathematics education literature, questions about the abilities of females are latent in the research. The aim of such research, it is argued, is to prove that the abilities of females are identical to those of males.

The author recommends that research questions be examined for hidden assumptions, primarily the assumption that females are not engaging in mathematical activity to

the degree that men are. Assuming that women are mathematical leads to a different understanding of both the nature of difference and of mathematics, and raises numerous unanswered questions. For example, if women are mathematical, what is "women's mathematics"? This raises further questions about the nature of mathematical knowledge and mathematical certainty which are critical for the mathematics classroom. The role of intuition in mathematics is one critical classroom concept which is explored.

The goal of research on gender difference, the author maintains, should not be to force females to pursue mathematics to the same level as males, but to develop new windows for examining mathematics teaching and learning, and to improve mathematics education. This will have benefits for all students in mathematics, those who are female as well as those who are not.

CHAPTER 1

BEGINNINGS

> Merleau-Ponty has reminded us that it is in a world already spoken that we speak. He understood that with every utterance we announce ourselves as members of human and historical communities. Our choices and expressions of meaning are connected to what has mattered in this world to the people who have cared for us. (Grumet, M., 1990, p. vii.)

> See here how everything lead up to this day. (The Grateful Dead, 1970)

I was born in 1964, as the Women's Movement was beginning to rise to the forefront of American culture. The struggles of these women, their goals, failures, and successes, have formed the cultural background for my learning and living, leading inexorably to this day. In the words of Madeleine Grumet, I have been, and continue to be, spoken by it.

As a student, I have been spoken into being by the schools I have attended and the teachers I encountered there. As a teacher, I am spoken by my students even as I speak them.

In *Exiles and Communities: Teaching in the Patriarchal Wilderness*, Jo Anne Pagano (1990) underscores the importance for feminists of understanding this cultural speaking. Because "oppressive practice depends on forms of expression organized oppositionally and hierarchically -- presence-absence, intellect-emotion, public-private, self-other, objective-subjective, male-female" (xix), feminist practice refuses the organization, reconnects the oppositions to one another. Therefore, in education, it becomes crucial for teachers to question the separating of presence from absence in educational discourses, to endeavor to speak the absences. It is into precisely such an absence that I enter the discourse on gender differences in mathematics.

Questions about gender differences in mathematics stem from the oppositions and hierarchies about which Pagano writes. Our understanding of gender differences have broadened since Elizabeth Fennema (1974) conducted a reexamination of research data collected in the 1960s. The questions she raised about such research inspired two decades of research designed to determine the nature and causes of gender differences, with the goal of developing the means to counteract the causes and so eliminate gender differences.

By concentrating on the inferiority of female learners of mathematics, Elizabeth Fennema (and those who have followed her) have contributed to the speaking of my absence. Unlike the female students in Fennema's studies, I have always enjoyed mathematics, have done well, and have been confident of my abilities. As a female from a working class home, my position in this discourse should be that of the majority it seeks to explain and alter. It is not, and my positioning is that of the deviating deviant: I am made different from men by my gender and different from women by my love of mathematics. I am divorced from mankind and from femalekind. This discourse silences me, forcing me into a tacit and ambiguous third category that is neither male nor female; it is from this feeling of "forced absenting" that my interest in gender differences in mathematics grows. In what follows here, a re-presentation of the presences spoken by the research, I am present, but only in the spaces. The stories and interrogations which follow are not merely academic exercises, but a search for myself as a learner, a teacher, and a person.

It is in the spirit of Pagano that I write this dissertation: It is a dialogue between myself and many others. The first conversation is between me and my self; it tells of my coming to hold the conversations that follow, what has "lead up to this day." Like the others, it is on-going; continuing even as we confront this text.

The conversations that follow begin with my understanding of the problem we face -- we do not know our own story. By opening conversations with ourselves, our histories, our epistemologies, our world views, we begin to bring our story into view. By recognizing ourselves as participants in the continual construction of our story we position ourselves as directors of that story, ready to write past, present, and future.

<u>School</u>

From the time I started school, I was a good student. I obeyed the rules set down by the teacher. I turned in completed homework assignments, mostly on time and mostly correct. I finished the sections on standardized tests with time to spare.

Like many children, learning to play the game of the school took me some time. Mrs. White, my first grade teacher, noted that I talked too much in class. Mrs. Thompson, in the second grade, noted that I did not use my time wisely and often turned in assignments late. However, these were the only poor conduct notations on any report cards issued to me in school. By the third grade I was properly conditioned.

In those two years and the years that followed, I learned a great deal *in* school and *about* school. For the most part, my teachers, like most teachers, were competent and concerned, and I responded by learning the material that they had to teach, re-displaying it for them in assignments and on exams. Whereas in first and second grades my boredom had gone unchecked, as I realized the nature of the rewards and punishments inherent in the system of school and how rarely were the assigned tasks truly difficult or the answers well-hidden, I learned to channel my boredom in acceptable ways. I discovered that reading was an acclaimed activity for free time; this activity allowed me temporary (mental if not physical) escape from the drudgery of school. Reading became to me what chocolate is to the long-term dieter: an exceptional and highly anticipated reprieve from denial.

Throughout my schooling I was rewarded for my cooperation and my ability to perform well those things deemed important by my teachers. I was a "good" student in the eyes of the school, for I learned early to hide my boredom and modify my behavior in acceptable ways. It seems almost coincidental that the primary way I adopted was to read, and that this was not only acceptable in most cases, it reinforced my status as a good student.[1]

I was reading when I started to school; credit for this goes entirely to my mother. She began reading aloud to me as soon as I began to speak and understand words; as I grew older, reading was a central part of my life. I read absolutely anything and everything I could, at every possible moment. Perhaps my favorite reading material was the set of encyclopedias in my parents' bedroom.

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[1]It did this in two ways. First, it is to my voracious appetite for reading that I attribute much of my school-like learning, rather than to school directly. Secondly, reading is regarded as an intellectual activity that students often must be prodded into doing. By reading voluntarily I presented myself to my teachers as a superior student who was interested in learning.

Aside from the encouragement and stimulation I received at home, I gained insight into the possibilities for learning at a summer program for students identified as intellectually "gifted," the Governor's Program for Gifted Children. I was tested in 1976, in the sixth grade, along with my classmates; no one told us why we were tested. Several of us scored well enough to undergo further testing away from school; three of us exceeded the cutoff for admission to this program. Only I attended.

I returned to the McNeese State University campus in Lake Charles for four summers after the first one. It was as a result of that program that I first learned to paint stage sets and to grow plants from cuttings. In my summers there, I performed in five musicals and two plays, read *1984* and *Waiting for Godot*, and was introduced to symbolic logic and the philosophy of Descartes. I learned to play spades (well) and Risk (not so well), and to "appreciate" the songs of Tom Lehrer. I served as a Justice for the Student Court and, along with two others, decided several cases brought against students in the program. I washed my clothes, formed opinions and questions about the nature of law and justice, managed my time, and forged new and lasting relationships with other students interested in academic and other pursuits.

My participation in this program connected me with learning in ways that school had not. We learned by reading, working, and discussing in the classrooms, laboratories, library, studios and theaters of the university. Unregulated by the demands of "regular school," the classes were designed primarily to stimulate interest rather than convey content. We were never given examinations; success was measured by the performance or painting or poem or story exhibited at the end of the summer for one another and our families. It was as a student in this program that I first began to see what learning and teaching could be.

Family

My mother went to school in a small farming community. Married immediately after graduating from high school, she never returned to school. She does not consider herself well-educated or particularly intelligent (although I disagree) but has always insisted that I be both. Growing up in that small town in southwestern Arkansas, the granddaughter of the local Baptist minister, she learned as a young girl the importance of acting appropriately, of being concerned -- as all proper young ladies should -- with how others viewed her, what they thought of her. In her own way, she passed this legacy on to me but with significant changes.

My mother graduated from high school in 1941; I started school thirty-nine years later in 1970. In that time, women had made strides toward opening employment and career opportunities that had been closed to them. My mother anticipated the meaning of those changes for my future, even though they had come too late for her.

However, her sensitivity to the scrutiny of others never waned. In 1976, she applied for my admission to the Governor's Program. It was extremely important to my mother that I be admitted, more so than it was to me initially. She was given a "Social History Worksheet" to complete as part of the admission process. While her answers to the questions are all strictly true, one of her answers to the essay question is somewhat at odds with my own memories. In answer to the question, "What kind of adult person do you want your child to be?" she responded:

> I want her to . . . make the most of her life in whatever she chooses to be; whether it be a nurse, teacher, housewife or whatever. Like any mother I want the best for her. And if to her the best is to be a wife and mother then that's what I want. Or if it's to be a teacher then that's what I want. In other words what I really want is her to happy with herself.[2]

The occupations listed by my mother may not seem unusual for a woman of fifty-three years writing in 1976; however, this is a list significantly changed from the one that was suggested to me. For me, it was the "whatever" that was elaborated. I could, she told me again and again, be

[2]This is from a form that was completed by my mother in 1976; I found a copy, in her handwriting, in a box of school papers as I was writing this dissertation.

"whatever" I wanted to be: a doctor, a lawyer, a scientist, or a "CPA, like cousin Joel," all of which I seriously considered at some time in my life.

No, it was not for me but for the scrutiny of others that this list was composed. Not daring to jeopardize my chances for admission to this program, my mother presented her wishes for me in what she saw as a more appropriate way, by providing a list of occupations that were "feminine" and "normal," and speaking the (preferred) absence by invoking "whatever." It is from her certainty about my capabilities and her consistent support that I attribute my confidence and success in schooling.

My father was also central to my schooling. Whereas Mother sparked my devotion to reading, Daddy contributed to my interest in mathematics, which is congruent with the results of research on parental influences on the success of females in mathematics (Franklin & Wong, 1987; Jayaratne, 1983; Morse & Handley, 1982; Schaalma, 1989; Wigfield, 1983; Yee, 1986). One particular memory involved negotiation between my father and me about computation and the algorithm that one uses, specifically the addition algorithm. I started school at a time when the ideas of New Math still held some sway over mathematics teaching and was required by my teachers to compute and to record my computations in a very specific manner. For my father, who was educated fifty years earlier in a one-room rural schoolhouse, the laborious process of addition (and, in later years, the remaining operations) that was required of me was ridiculous. At the tender age of six, I found myself in the position of mediator between (at least) two different philosophies of education in mathematics.

My father worked as a clerk in the United States Air Force for twenty-two years and for the Arkansas Louisiana Gas Company for thirteen; computing quickly and accurately were fundamental to his job. Although he always had an adding machine on his desk, he trusted his ability to compute mentally, knowing that he could be just as accurate and faster. The mental skills that he had honed for years, however, were a hinderance in his attempts to help me to understand and perform in the manner that was required in school. Further, my own youth and inexperience left me without the necessary ability to mediate the dissonance created by his explanations and the dictated algorithms. A final obstacle to our communication was the perceived rigor of the algorithms -- no deviations or alternatives were allowed for school mathematics. How, my father inquired again and again, was one to master addition when one was forced to waste time recording needless steps in the process? The correct answer could be arranged by grouping and summing mentally.

Tied to this memory is my recollection of memorizing the multiplication tables. Each night, following the family meal, I recited the multiplication tables, beginning with "two times two is four." ("One times one is one" and the like held no interest for my father; the "one's tables" were obvious and required no memorization.) I recited the tables in order each evening, going out to play only after satisfactory competence had been demonstrated. My father did not cruelly deny me exercise and fresh air, he simply wished to ensure that I possessed basic knowledge without which he knew I could not be successful in mathematics; mathematics, he assured me, would be important to me in the future. He was also pleased by my ability in recalling these facts, for I mastered the lists quickly.

Neither of my parents attended college, but both insisted that my sister and I obtain at least one college degree. My interest in mathematics was fed by my father from an early age; my scholastic pursuits were constantly and consistently praised and supported by my mother. Together my parents gave me a determination to realize my educational goals and an affinity toward mathematics. In high school, when I was purportedly allowed to select my own path, I automatically chose "college prep" courses, emphasizing mathematics and science. Although I felt drawn to numerous career paths, I knew that mathematics would be a central feature of any path that I chose.

University

I began my undergraduate work by majoring in chemical engineering. Once I started college and enrolled in a computer programming class, I felt that I had truly found my niche. I enjoyed (and continue to enjoy) exploring the power of the computer to calculate, summarize, organize, and output data. I was employed as a programmer in a program for college students for two summers by the company where my father had worked; in the intervening school year, I changed my major from computer science to accounting, a move prompted by a coworker who indicated that finding a programming position in a business might be easier with a degree in accounting and experience in programming. However, this experience in full-time programming revealed to me my need for personal contact; I knew that I could not spend my employed life facing a computer screen for eight hours with my back to the other people in the office.[3]

My final change of major from accounting to secondary mathematics education came soon after I acknowledged to myself that I did not want to program computers for the

[3]It seems somewhat odd to find myself doing precisely that as I write this dissertation.

remainder of my life. I always had a denied, almost guilty, desire to teach, which I acknowledged at this time. Like most students in education, I was actively deterred from that course by my parents, friends, and teachers. I made the conscious choice at that time to ignore the warnings and follow my own path, focusing on my love of mathematics and my desire to inspire and challenge others mathematically.

Feminism

Before beginning graduate studies, I considered myself "liberated" in the popular sense. That is, I was concerned about equal pay and access to jobs and promotions. I insisted that housework and child care were equally the responsibility of men and women, particularly when both spouses are employed outside the home, and was (am) an outspoken proponent of choice. These attitudes were cultivated by the early encouragement to be independent given me by my mother; she had herself lived a very traditional life: two children, no employment outside the home. However, she seemed able to intuit the changes that were in coming for women in the 1970s; her age[4] had separated her, not me, from those changes. Limited by the financial and cultural restrictions imposed

[4]My parents were roughly the age of my peers' grandparents when I was born; my father was 50, and my mother was 41.

on women in the 1930s and 40s, my mother fashioned her life within her boundaries; her understanding of women's rights and the new boundaries, as passed to me, rejected any notion of gender restrictions on intellectual growth.

Although I was committed to many of the ideals that I now realize can properly be called feminist, I actively denied that I was, indeed, a feminist. When I was in high school, with Ronald Reagan beginning his eight-year tenure in the White House and conservatism the accepted political stance, feminism implied burning bras, drafting women and using unisex restrooms in public areas.[5] I was unaware of a multiplicity of feminisms, or that feminists could differ so markedly in their interpretations of what constitutes feminist thought and action. I had yet to understand how much of what I desired for myself, and many things that I took for granted, were a result of feminist struggles both before and during my lifetime.

My first semester of full-time graduate work offered me the opportunity to investigate feminist theory, in the form of a course. New insights into the debates within and between feminisms, coupled with my personal commitment to mathematics education, sparked the interest in current research developed here. What kinds of feminist understandings and assumptions are inscribed in the

[5]It never bothered me, or even occurred to me, that this is precisely what the bathroom in my house was.

various strands of research in mathematics education? How do feminists with different theoretical stances view the common notion that women are not mathematical? The distinctions drawn by Alison Jaggar in *Feminist Politics and Human Nature* (1983) between liberal feminism, traditional Marxism, radical feminism, and socialist feminism remain central to the development of my curiosity about gender and mathematics education. Jaggar's exposition of the philosophical understanding of human nature that is implicit in each of these categories, as well as their political implications, provoked my interest. That interest has led me to explore the tacit beliefs about the nature of human beings, learning, rationality, individuals, and mathematics that underpin research in mathematics education and gender as well as my own understandings of my place within that research.

As I moved from teaching mathematics to teaching mathematics teachers, I began to wonder why I was so different. That I was different became increasingly clear; as I probed the literature in mathematics education and differences in gender, the sense of aloneness that I had first experienced in elementary school began to grow. Where was I to locate myself and my experiences in a field which presented girls as poor mathematics students? Where were my male classmates, who detested mathematics and who opted out at the first opportunity? Why did (does) this research insult me so?

This work, then, in part represents my quest for myself -- and other women -- in this body of literature. It is fueled by my ever-increasing joy in mathematics, in being mathematical, my desire to share that joy, and my commitment to my belief that all of us possess at least the potential to be mathematical. It also represents my continuing effort to understand all forms of feminism and to understand and articulate my own feminist philosophy.

Recent scholarly interest in gender differences and mathematics learning surfaced in a femininst climate dominated by the ideals of liberalism. In order to reveal the shape of current work, it is necessary to look briefly to the beginnings of the feminist movement for the origins of current questions in mathematics education and gender. An understanding of the origins of the questions currently dominating the field is critical to a feminist analysis of the research.

But the roots of recent research extend farther than the feminist movement of the past twenty years. Questions of gender and mathematics cannot be extricated from the sense of emergency that has pervaded mathematics education since the launch of Sputnik in 1957. Confronted with a national crisis, the American public latched on to mathematics and science education as the key to military and economic security, a hope which continues to dominant the educational landscape. The push to increase the ranks of scientists in this country sparked increases in mathematics courses and enrollments. This continuing campaign and the emergence of feminism in the popular arena form the cultural milieu in which research in mathematics education and gender are entangled: Any understanding of the current research cannot be attempted without a brief survey of the larger picture.

This look to history begins in chapter 2 with a review of literature on gender differences in mathematics. Although gender is not necessarily primary or separate as a body of experience, the research on gender differences has, for the most part, investigated the relationship between gender and mathematics learning separately from other cultural groups; because the present work is a general examination of literature, understandings of gender frame this writing. This body of work is then re-framed within the national response to the crisis of Sputnik in chapter 3. Chapter 4 returns to the issue of gender and mathematics education, but rejects the criterion of a masculine norm against which the accomplishments of females are to be measured and raises questions about the definition of mathematics and mathematical knowing assumed in difference research. The way in which "mathematics" is understood has had profound effects on the study of gender differences, which assumes that mathematics as legitimated and understood by men is the only mathematics which exists. In the final chapter, I conclude by suggesting alternative ways of understanding the nature of gender in mathematics learning, the mathematics classroom, and by proposing a research agenda that complements this understanding.

CHAPTER 2

US OR THEM:
LOCATING AND REDUCING DIFFERENCES

> In those languages that assign gender to words, the word *mathematics* is feminine, but *mathematician*, meaning the studier or doer of mathematics, is masculine. Herein lies the crux of the mathematical mystique. Is the world of mathematicians truly a masculine domain, into which women must venture with caution and trepidation? Are women who have entered it more "masculine" than other women? In what ways do females differ from males with respect to mathematical achievement and ability? To what extent can these differences be attributed to the self-fulfilling prophesy and socialization experiences at home and in school that reinforce the mathematical mystique? What research evidence suggests ways to remediate the results of or prevent the avoidance of the study of mathematics and careers in which high-level mathematics skills are required? (Fox, 1980a, p.1)

> Women are deficient in Reason but abundant in Emotion, [and] they ought [not] be treated as rational. . . . Behind their backs they are both regarded and spoken of -- by all except the very young -- as being little better than "mindless organisms." (Abbott, 1884/1952, pp. 49-50)

In the decade that followed the re-emergence of feminism in the United States, the spotlight of feminist scrutiny grew wider and brighter, encompassing more and more aspects of life in the United States.[1] A few women

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[1]Clearly, a statement like this one blatantly ignores the critiques of minority women that mainstream feminism has largely ignored their needs and interests, concentrating exclusively on the problems of white, middle

began by probing the gendered nature of housework (Freidan, 1963) and the airline industry (Davis, 1990); their rage at the sexism they uncovered opened the floodgates to the surge that has been termed the "second wave" of American feminism.

This problematic label is used to distinguish the most recent period of feminist activity, beginning in the 1960s, from the struggle for women's suffrage in the early part of this century. This usage, however, serves to perpetuate a false impression of feminist inactivity between the two periods and functions to divide and disempower women. As a "new generation" finds itself facing a backlash from the religious and political right, younger feminists are now members of the "third wave," a label which deprives them of the centuries-old history of feminist struggle. Separating feminism into "waves" is a way of fracturing the efforts of women across age and across time that "erases our ancient, multiracial, cross-cultural history and limits our constituency" by asking veteran feminists to "pass the torch" (Morgan, 1993, p. 1) to a younger generation. Although the usage is prevalent in the literature, I will not adopt it here. In fact,

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class women. While I do not wish to perpetuate this attitude of exclusion, mainstream first generation research in mathematics education has also been largely race- and class-blind. Therefore, I have focused this chapter on recent feminist activity as it has most directly influenced the bulk of research in mathematics education.

this dissertation represents, among other things, an attempt to write against the grain of feminist waves, to re-introduce a general frame of our history as women and men, and as teachers, learners, and doers of mathematics.

This historical background does not attempt to provide and prove a seamless theory of the historical development of interest in the mathematical development of women; it is not a *total history*, but a *general history*. As Foucault (1972) points out, a total history is one which "seeks to reconstitute the overall form of a civilization . . . [to reveal] the significance common to all the phenomena of a period, [and to prove] the law that accounts for their cohesion" (p. 9). A general history seeks to

> determine what form of relation may be legitimately described between . . . different series; what vertical system they are capable of forming; what interplay of correlation and dominance exists between them; what may be the effect of shifts, different temporalities, and various rehandlings [of them]. (p. 10)

Rather than demonstrating a cause-and-effect relationship between the historical events described, this chapter will provide a view of the complex networks of interlocking events that served as the stage upon which the drama of women's participation in mathematics education has been examined.

<u>The Burgeoning of the Women's Movement</u>

As the struggle for suffrage ended in the early years of this century, the feminist movement in the United States divided over the Equal Rights Amendment (ERA), with one side demanding absolute equality under law and the opposition resisting the abolition of labor laws that protected women. The rift in the feminist movement centered around two conflicting views of women: equality proponents saw women as basically similar to men, and supporters of protection for women viewed them as more vulnerable, "doubly burdened as they often were by job and motherhood" (Davis, 1991, p. 32).

This rift resurfaced in the conflicts between liberal feminism and women's liberation in the 1960s. Committed to reform, liberal feminists concentrated their efforts "on opening up the male world to women at all levels" (p. 68), and focused attention on legal and cultural barriers to the success of individual women. The women's liberation movement was an offshoot and occasional competitor of liberal feminism, and "women's libbers" were generally younger, more radical, and were veterans of the civil rights and peace movements. Although the efforts of these women were instrumental in opening feminist discourses to the voices of poor and minority women, in the early 1970s liberal feminism became the mainstay of the struggle "almost by default" (p. 137), as most of the original women's liberation groups died out.[2]

The resurgence of the feminist movement in the United States cannot be traced to a single event or a single area of life. It followed on the heels of the civil rights and peace movements, but these are not its only roots. It began, too, in the battles between airline stewardesses and airlines over age and marriage restrictions, and in the demands of women for equal access to elite, male-only institutions of higher education (Davis, 1991). Additionally, women who had influence in Washington, D.C. contributed their efforts to ensure basic legal rights for women. And others challenged the doctor's office, exposing sexism in medical treatment for women (Mendelsohn, 1981; Roberts, 1981; Scully, 1980). Historian William Chafe (1972) highlights the dominance of liberal feminism in his description of feminist efforts:

> Female activists picketed the Miss America contest, stormed meetings of professional associations to demand *equal employment opportunities*, and forced their way into male bars and restaurants in New York. They called a national strike, wrote about the oppression of a "sexual politics," and sat in at editorial offices of *Newsweek* and *Ladies Home Journal*.[3]

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[2]For simplicity, "feminism" will be used for the time being to describe the efforts of the mainstream, that is, liberal feminism; the implications, problematics, and critiques of liberalism are addressed in chapter 3.

[3]They did not, however, burn any bras. At the Miss America pageant protest, "protestors crowned a live sheep Miss America . . . [and] tossed curlers, girdles, high-

> At times, it seemed that the media had been taken over by women's liberation, so often did female activists appear on network television and in national magazines. In an era punctuated by protest, *feminism* had once again come into its own. If not all women subscribed to the new fight for *equality*, an energetic minority nevertheless believed that the time had come to finish the task of gaining for women the *same rights* that men had. (pp. 226-227; italics added)

In a few years, the movement had exploded onto the cultural scene. Flora Davis (1991) notes that "people spoke of 'sexism' and 'male chauvinism'" (p. 16), and "in the early 1970s, feminists set out to change American education . . . at every level from kindergarten through graduate school, from the content of textbooks to the way colleges hired faculty" (p. 204). The efforts of feminists were widely distributed: some fought to gain knowledge about and control over medical treatment (The Boston Women's Health Book Collective, 1976, 1992; Roberts, 1981); others filled in gaps in history (Alic, 1982; Lerder, 1977, 1979; Levin, 1980; Lopate, 1968; Lutzker, 1969). Feminists objected to the sexist presentation of women in textbooks and other school materials (Council on Interracial Books for Children, 1977; Davis, 1991; Downer, 1982) and discussed how to rear

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heeled shoes, women's magazines, and the odd brassiere into a 'freedom trash can'. . . . No one lit a match to the trash can -- America's most famous bonfire was strictly a media invention" (Davis, 1991, p. 107).

children in nonsexist ways (Greenberg, 1978; Pogrebin, 1980).

Interest in the education of women emerged early in the crusade for equality. In 1962, the Itasca Conference on the Continuing Education of Women convened in Itasca State Park, Minnesota. At the end of the conference, Margaret Culkin Banning (1963) concluded:

> We are certain that the need and desire for continuing education of American women is not regional but national. . . . The fires of interest have sprung up in noncontiguous areas and have not been started by one hand. The roots of the movement seem to be in the unused or undeveloped abilities of women and the conscientious belief of women, educators, and citizens that we are permitting a waste of ability that we cannot afford. (p. 143)

Within a few years, the "fires of interest" were raging widely and wildly, leaving permanent marks on the face of education in the United States.

In the 1970s and 80s, interest in the relationship between education and gender blossomed. Women discussed the ways in which schooling contributed to gender oppression (Deem, 1980; Epstein, 1970; Frazier & Sadker, 1973; Grambs & Waetjen, 1975; Maccoby, 1966; Maccoby & Jacklin, 1974; O'Kelly, 1980). They rejected the male bias of traditional history and began exploring women's history (Baum, 1986; Chafe, 1972, 1977; Dick, 1981; Grinstein & Campbell, 1987; Higonnet, Jensen, Michel, & Weitz, 1987; Janssen-Jurreil, 1982; Kennedy, 1983; Lerder, 1977, 1979; Osen, 1974; Perl, 1978; Stein, 1985).

Feminists exposed the barriers to and problems for women in professions like engineering (Hacker, 1982, 1983) and medicine (Beshiri, 1969; Lopate, 1968; Lorber, 1984; Mendelsohn, 1981; Muff, 1982; Scully, 1980; Walsh, 1977). Recognizing mathematical training and ability as a *critical filter* (Sells, 1973) in obtaining employment in heretofore "male" domains like medicine and engineering, feminists began to examine the simple explanations for female underachievement and underparticipation in mathematics.

It is not surprising that as women investigated the ways in which society operated to direct the current of female life in particular ways that attention turned to examining the role of education. In general, these activities divided along two paths: (1) exploring and challenging the mechanisms by which the intellectual activities of women were directed towards "feminine" fields, like nursing or education, and away from "masculine" fields, like engineering or law; and (2) investigating the basis for differences between the achievements (usually defined by occupational choice) of females and males.

As one of the few experiences that is common to all, the process of schooling was and continues to be an area of interest to feminists. Although the relationship of gender to learning has been explored and theorized for millennia, feminists sought to undermine prevailing opinions regarding the possibilities for the education of women. In the three decades that have followed the reemergence of feminism, various facets of education have been examined to determine how understandings of gender are related to schooling. Although this work continues in all the disciplines represented in schools, it is the investigation into mathematics and science that is of particular concern here.

In 1974, Elizabeth Fennema[4] directed this energy toward mathematics education, probing the relatively small body of relevant literature produced in the previous decade to determine to what degree the belief that boys learn mathematics better than girls was supported by research. Finding insufficient evidence to confirm this belief, particularly at higher grade levels, Fennema and others continued this investigation in subsequent studies (Fennema and Carpenter, 1981a, 1981b; Fennema and Sherman, 1977, 1978; Fennema, Wolleat, Pedro, and Becker, 1981; Sherman and Fennema, 1977). One significant result of these and other, similar studies was an increasing

[4]Elizabeth Fennema clearly was not the first or only researcher to publish in the area of mathematics and gender; however, given the importance of her work, and the volumes of research that she and various colleagues have produced, she is commonly given credit for following a sounder research program than her predecessors and for stimulating greater interest and research in the field.

awareness of the complexity of the relationship between gender and mathematics learning.

This research, and much that has followed, is typical of first generation feminism (Noddings, 1990b), in that it seeks an understanding of how females differ from males, where masculinity is accepted as the norm; in work of this type, femininity gets defined, albeit not explicitly, as deviant in relation to this masculine norm (Gilligan, 1982). Although numerous insights into the relationship of gender to learning mathematics have been gained from first generation work, critiques of "male as norm" have led feminist researchers to the second generation. Before turning our attention to critiques of the first generation and the work of the second, however, a deeper consideration of the understandings gained from first generation investigations is warranted.

An Old Question

Questions about the different natures and abilities of women and men have occupied the interest of philosophers and scholars for generations. Dominated by males, philosophical discourses on sex-linked differences have historically centered on the ability of women to conceive and bear children, have assumed masculinity as the norm from which women deviate, and have sought to articulate the nature and effects of that deviation (Agonito, 1977).

Specifically, interest in sex-linked differences in learning mathematics preceded the explosion of research effort in this area following the reemergence of feminism in the United States. In the period from the mid-1950s to the early 1970s, researchers in mathematics education expressed concern with why "Johnny" could not add (Fang, 1968). Common wisdom of the time stated that, while Johnny could not read either, mathematics was "his" strength whereas language was the strong subject for Jane. Maccoby (1966; also, Maccoby and Jacklin, 1974) concluded from the literature on sex differences that, although there was no clear indication that either sex was generally more intelligent than the other, there was sufficient empirical evidence to support the belief that girls have superior verbal ability and, in the long term, inferior abilities in arithmetic reasoning, spatial ability, and in the ability to restructure problems creatively.

This conclusion was supported by the data collected for Project TALENT, a large-scale testing effort designed to identify talented high school students (in the spirit of post-Sputnik concerns). Project TALENT researchers tested hundreds of thousands of high school seniors in 1960, and included interest and attitudinal inventories in addition to the battery of academic tests, which focused primarily on mathematical, scientific, and technical aptitudes. Like previous research on sex differences, the Project TALENT data indicated that, among high school-aged students, boys were much more likely than girls to have interests and abilities in quantitative and/or scientific areas.[5]

The bulk of such research in the 1950s and 1960s seems to have been less directed at ways to increase the mathematical abilities of young women than in determining appropriate expectations of students based on gender. For example, a study reported in *Journal of Educational Psychology* (Sommer, 1958) compared the ability of women to men in remembering quantitative information embedded in a paragraph. Sommer's results suggested that women were not as capable as men as recalling quantitative information from paragraphs, but these same women demonstrated ability equal to that of the men in recalling *decontextualized* numbers of six or seven digits.

Sommer concluded that this may indicate that "many women are unable to retain *large* numbers (thousands or millions)" (p. 191), in spite of his own research data. Clearly, the women were able to retain numbers in the

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[5]Wise, Steel, and MacDonald (1979) found that differences in the number of mathematics courses taken by female and male students accounted for virtually all the discrepancies reported in the Project TALENT data.

millions, for they recalled the decontextualized six- and seven-digit numbers at the same rate as the men in the study. The problem with the recall of the women seems not necessarily to be in remembering the numbers themselves (as Sommer concluded) but may well stem more from the contexts in which the numbers were presented. For instance, it may be easier to recall a seven-digit number presented without context if one likens it to a phone number. However, when the same number is presented as the population of Bombay or as the number of barrels of oil shipped from Venezuela each month, the lack of familiarity or interest in the presented material, or other distractions of context, may account for observed discrepancies.[6]

Sommer's study is mentioned here to illustrate[7] that gender research in mathematics education prior to the early 1970s was not limited merely to broad statements of male superiority in mathematics and science. Some effort was expended to determine which gender excelled in

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[6]It is interesting to note that the type of error Sommer highlights is one of significant places; i.e., writing 12,000 for 120,000 or 1,016,000 for 116,000. It has been suggested (Paulos, 1988; 1991) that most people have difficulty interpreting and remembering large numbers, due in large part to a general lack of understanding of differences in the magnitudes of large quantities.

[7]The studies cited here are representative of research of the period; see Fennema's (1974) seminal summary of major research in mathematics education and gender conducted in the 1960s for other examples.

specifically conceived areas of mathematics (arithmetic, problem solving, spatial reasoning). However, the reports of research on gender differences that was conducted in the 1950s and 1960s do have the flavor of sexism. In other words, the interests of the researchers seemed to lie more in maintaining the inferiority of female mathematics students than in investigating the roots of difference.

Two examples will clarify this point. The first is a longitudinal study of changes in intelligence test scores during college and how those changes related to gender. The researchers expected to find that college males gained more than college females, based on research that suggested that females "average slightly higher than boys until at least the age of 16" (Charles & Pritchard, 1959, p. 43). But the males in the study made no significant improvement in their scores during this time whereas the females did. Nevertheless, Charles and Pritchard conclude that "the equalization of the sexes in ability must occur in middle to late adolescence" (p.44), the period of time separating the two periods under consideration.

Finally, in a study of sex differences in class rank at the high school level, Arwood Northby (1958) found twice as many females as males in the top 20% of the sample, and significantly more males in the bottom 20% of the same sample. The importance of this data, Northby maintains, is to point to a problem in college admissions: "If rank alone is used for selection to coeducational colleges, the character of these institutions obviously would change markedly" (p. 64).

Each of these studies reveals an implicit goal of the researchers of thie period: to "uncover" the "truth" about female inferiority in mathematics. Such studies present "evidence" gathered in the effort to support the conclusion which has already been established. When the data fail to support the desired conclusion, some factor outside the scope of the study is invoked to explain the failure; clearly, the conclusion cannot doubted. To do so is to risk some marked change in the character of academic and other institutions by allowing women full access to them.

A New Look

What feminist researchers were able to introduce into the field was a greater skepticism about prevailing beliefs regarding the nature, extent, foundations and implications of those differences. For example, prior to the groundbreaking work of Elizabeth Fennema (1974), researchers had reported primarily on differences in *ability* in mathematics (Poffenberger and Norton, 1959; Riffenburgh, 1960; Stinson and Morrison, 1959); few studies compared differences in *achievement* (Aiken and

Dreger, 1961). Fennema's work was instrumental in shifting the attention of researchers to achievement, a variable more readily measured and addressed than ability (Crockett & Petersen, 1984).

In 1974, Fennema's seminal paper, "Mathematics Learning and the Sexes: A Review" appeared in the *Journal for Research in Mathematics Education*; this publication launched three decades (and counting) of research on gender differences in learning mathematics. This paper not only revealed that most studies conducted after 1960 did not clearly establish the existence of differences between the sexes, but, perhaps more importantly, raised troubling questions about the conclusions that were reached in these studies, that differences existed and favored boys. In her re-examination of this body of research literature, Fennema made generally accepted answers regarding both the nature and direction of gender differences less acceptable, opening mathematics education to the floodwaters of feminist research.

There is no indication in the literature that these early researchers had been deliberately misleading in the presentation and analysis of data, including those whose conclusions were subsequently rejected. Rather, in retrospect, it seems that the belief that males have higher ability in mathematics was so pervasive that researchers simply sought evidence to show when and where differences appeared. In the face of less-than-clear data, then, these researchers could have been led by the strength of their beliefs, and the lack of a reasonable challenge to those beliefs, to conclusions not fully supported by the data.

Fennema's challenge to accepted wisdom was soon picked up by other researchers. In 1979, Wise, Steel, and Macdonald re-examined the conclusions derived from the Project TALENT data collected in 1959 and 1960; they showed that all of the differences attributed to gender in the original analysis disappeared when the number of mathematics courses taken was controlled. It was not surprising that women as a group performed at a level below males as a group because females had been compared with males who had taken as much as six semesters more mathematics. When the analysis was adjusted to compare groups with similar course-taking behaviors, the differences disappeared (Wise, Steel, & MacDonald, 1979).

But the questions that Fennema's initial paper inspired went beyond mere re-examinations of old data. Prior to her work, researchers had assumed (believed) that differences in achievement and interest in mathematics were due to some sex-linked difference in ability; as researchers began to question that assumption (Crockett & Petersen, 1984), and cast doubt upon the data used to support that claim, other questions began to arise and new research was conducted.

The Biological Basis[8] of Inferiority: Moving Backwards in Time

The argument that women's inferiority is rooted in biological differences is one of the most ancient of philosophical discourses, and justifications for its acceptance have fluctuated throughout the ages. Plato and Aristotle held opposing views on the inferiority of the female, with Aristotle advancing the position that woman's inferior biology renders her inferior mentally and spiritually (Agonito, 1977). Although the status that variations of this argument have enjoyed has waxed and waned through the ages and cultures of Western history, it has never truly disappeared from the discourse on gender.

Although Plato himself disavowed the notion that the biology of gender determines the differences between women and men, his version of a social order based on "inherited, inborn distinctions" (Gould, 1981, p. 20), the "metal" of which different classes are made, ultimately contributed to the birth of scientific investigations into the biological bases of differences in races, sexes, and

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[8]I have summarized and compressed the arguments surrounding biological determinism, but interested readers should see Sayers, J., (1982), *Biological Politics: Feminist and Anti-feminist Perspectives*, London: Tavistock, for an excellent treatment of the history and problematics of biological determinism.

classes of human beings. In his historical analysis of the science of differences, Stephen Jay Gould (1981) traces the evolution of *biological determinism*, the argument that inequities in the social order are the natural and accurate reflections of inherent biological differences. Proceeding from this premise, determinists have used various (and often spurious) means to locate the origin of differences within the human body.

Considering the relationship between social gender and biological sex continues to raises difficult problematics for feminist theorists (Malson, O'Barr, Westphal-Wihl & Wyer, 1989; Sayers, 1982); biological determinism can be invoked in liberatory, as well as oppressive, situations. While biological differences have often been used as the basis for discriminatory practices, they may also serve to privilege women's positioning, particularly with respect to child-rearing and mothering; that women are much more likely than men to be awarded child custody by the courts is an example of biology-as-privilege. The tension between biology-as-privilege and biology-as-handicap has been explored in the work of numerous feminist writers (Jaggar, 1983; Sayers, 1982); it is the notion of biology-as-handicap which troubles research on sex-related differences in mathematics learning.

Most often, deterministic arguments have centered on the ability of the female to menstruate, conceive, and lactate. These biological processes have forever bound woman, at least as far as (male) philosophers and theorists have been concerned, to the process of procreating the species, and thus to sentimentality and nurturance. The importance of such processes cannot be challenged; the perpetuation of humanity depends upon these capabilities and the willingness of women to engage in them. According to adherents of biological determinism, the need for procreation is so fundamental that nothing can be allowed to interfere, including the development of individual intellect (Gould, 1981). Nevertheless, however critical procreative functions may be, feminists argue, women must not be bound only to this activity. Not merely demeaning to women, this mentality deprives all humanity of the intellectual, social, political and professional contributions that women can make.

The importance of procreative functions has been used to exclude women from educational experiences (because of our "natural" positioning as emotional rather than rational persons) and further used to stimulate fears that female scholarship could lead to sterility (Sayers, 1982). The uterus was now no longer invoked as the location of differences within the body for craniometry relocated differences in intellectual ability in the brain (Gould, 1981). Although advances and changes in craniometric understandings led to the abandonment of the study of the physical size and shape of the brain, some researchers continue to hope that an immutable physical difference can be shown to limit the intellectual potential of one of the sexes.

The notion that differences in the number of women and men who pursue higher-level mathematics is due to some fundamental biological difference is a compelling one for many theorists. In the search for evidence that biology determines intellectual ability, researchers have looked to genetics, to the levels of sex hormones in the body (both before and after birth), and to the structure of the brain for answers. In a review of the literature, Crockett and Petersen (1984) concluded that sex-linked differences in cognitive abilities cannot be explained by genetic factors, and that the data available on connections between the levels of estrogen and androgen produced in the body and sex-related differences in mathematical achievement are "largely inconclusive" (p. 98). Nevertheless, Thomas Hoben (1984) proposed a theory which assumes that a recessive gene linked to the X-chromosome facilitates high mathematics performance. This theory, in his estimation, explains the differences in scores for high-achieving junior high school students on the mathematics portion of the SAT; Hoben's tenacity and temerity, in light of the contradictory and insubstantial nature of the data, are characteristic of determinist writers.

In addition to the levels of sex hormones and the impact of genetics on mathematics learning, determinists have looked to differences in brain structure to explain differences in mathematics performance. There is some evidence that the brains of females are less *lateralized* than those of males (Crockett & Petersen, 1984) although differences in lateralization are not always found and are not always found in the same direction (Bleier, 1984). Brain lateralization refers to the degree to which the hemispheres of the brain operate independently of one another. In general, though differences in lateralization do not always appear in a specific brain, the brains of women display greater interconnection between hemispheres, which has led some researchers to conclude that women process information in both hemispheres to a greater degree than men (Bleier, 1984).

Although it may be the case that the brains of women and men differ in ways that are germane to mathematics education, too little is known about how the brain functions to draw any firm conclusions. Crockett and Petersen (1984) note that the brains of females and males are much more alike than different, and that it is impossible to disentangle biological factors from cultural factors when conducting research on the human brain. In her scathing critique of sex differences research that looks to the brain for answers, Ruth Bleier (1984) concludes that

> studies linking hormones with . . . achievement and intelligence or linking "innate" differences in brain structure with sex differences in verbal, mathematical, and visuospatial abilities have been methodologically, logically and conceptually unsound and inconclusive. (p. 108)

Bleier notes that researchers in this area start with "the very questionable assumption" (p. 92) that sex-linked differences occur, then look to brain lateralization, hormonal levels, or genes for differences to support the assumption. Bleier concludes her critique by referring to differences in socialization, ignored by determinists, and points to a hidden agenda in this research. She says:

> The enormous differences in socialization factors are more than adequate to explain the almost trivial differences that exist in mean scores without speculating about the differential evolution of female and male brains, of which nothing is known. . . . What the studies are in fact trying to explain are the more widespread differences that exist between the sexes in status, privilege, or power within known industrial, patriarchal systems, and they do this through attempting to scientifically establish biologically determined, sex-differentiated cognitive and personality characteristics that would make women's subordinate position inevitable. (p. 109)

Although the specter of biological determinism continues to hang over research on sex-related differences in mathematics education, most researchers in the field have turned to other, more explorable and tenable factors to explain observed differences in achievement, factors which allow the possibility for equal participation of women in mathematics. It is to this mainstream of research, which has rejected biological determinism in favor of other theories, that we now turn.

If Women Are Not Inherently Inferior, Then Why Is Mathematics So Male? and Other Questions

As studies emerged that confounded the belief that males possess superior ability in learning mathematics, researchers were confronted with indisputable evidence that women were less likely to enter fields that are highly mathematical. If, as researchers were concluding, women are not *inherently* less able in mathematics, why are women less likely to enter mathematical[9] fields than men? For answers, many researchers turned to the process of course selection in high school and college, looking for differences in the amount and kind of encouragement and information given to students of both genders by school personnel, parents, and peers (Armstrong, 1985; Brody & Fox, 1980; Franklin & Wong, 1987; Grambs & Waetjen, 1975;

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[9]The use of "mathematical" or "mathematics-related" to describe scientific and technological occupations or college majors is both common and disturbing. I have adopted the convention for ease of understanding and readability here, but it is a revealing convention that is analyzed below.

Jayaratne, 1983; Luchins & Luchins, 1980; Morse & Handley, 1982; Schaalma, 1989; Stallings, 1985; Wigfield, 1983; Yee, 1986).

What these investigations reveal is not surprising. Researchers found that the counselling students receive about course selection varied by gender, with males receiving greater encouragement in mathematics and science (Astin and Snyder, 1984). They pointed to the absence of strong female role models, both in schools and in textbooks, as contributing to the common perception of mathematics as a male domain (J. Ernest, 1976; Luchins and Luchins, 1980), as well as to textual depictions of women as mathematically inept (Tobias, 1978). Like previous studies, each of these helped to illuminate the complex social processes which shape the aspirations of females and males in schools and in society.

Questions about the discrepancy between the number of women and men pursuing mathematics-related careers were of no small importance, for researchers had found overwhelming evidence to support the notion that mathematics functions as a critical filter in the employment choices of women (Sells, 1973, 1980; Tobias, 1978). Opting out of mathematics courses in high school places limits on future decisions that are difficult to overcome. These future decisions involve both admission to selective colleges and graduate programs, and admission to specific programs within universities that require higher mathematics. Fennema (1984) conceded that "adult differences in mathematics-related careers cannot be totally traced to differences in course taking" (p. 140) in high school, but the exclusion of women from highly mathematical fields continues to contribute to women's high rate of poverty (American Association of University Women, 1992).

Although questions regarding the amount and type of encouragement given to young women by counselors, teachers, and parents continued to be of concern, other researchers looked to differential treatment within the classroom to explain differential participation patterns. Eccles, et al. (1985), in a study of the effect of teaching style on gender differentiation in mathematics performance, found no significant correlations between "teacher-style variables" (p. 114) and student attitudes toward learning mathematics. In a review of the literature on teacher effects, Lockheed (1984) concluded that a small group learning environment is more conducive to gender equity than teacher-centered whole group learning.[10] In a recent recapitulation of findings in

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[10]This finding is the most common; however, in a study of cooperative learning in mathematics, writing and reading in third, fourth, and fifth grade classrooms, Glassman (1988) did not find any differences between cooperative classes and traditional classes on achievement, gender or race relations, or student attitudes.

teacher-student research, Leder (1990a) noted that "research has indicated that teachers often interact differently with their male and female students, with males attracting more and qualitatively different interactions" (p. 17). The relationship between teacher behavior and student achievement has been widely studied both in education generally and in mathematics education in particular (Becker, 1981; Brophy, 1985; Brophy & Good, 1974; Brunson, 1983; Butler, 1989; Eccles & Blumenfeld, 1985; Fennema, Reyes, Perl, Konsin, & Drakenberg, 1980; Glassman, 1988; Hart, 1990; Macfarlane & Crawford, 1985; McDermott, 1983; Peterson & Fennema, 1985; Sangster, 1988; Sangster & Crawford, 1986; Stanic & Reyes, 1986; Walden & Walkerdine, 1985). The findings of these studies have yielded no consistent conclusions regarding the relationships between teacher-student interaction patterns, or coeducational versus single-sex schooling, and gender differences in mathematics.

Differential treatment of female and male students by teachers of mathematics is of particular concern in that this often unwitting behavior could have detrimental effects on the attitudes of females toward learning mathematics. The relationship of mathematical disposition to performance and retention in mathematics courses has implications beyond gender (Bassarear, 1986; Bretscher, 1989; Hart & Stanic, 1989; Randhawa, 1989), but researchers of the first generation have closely scrutinized data on mathematical disposition for clues to explaining recorded differences in performance by females and males in mathematics classes (Biaggio & Pelofski, 1984; Blum-Anderson, 1989; Coladarci & Lancaster, 1989; Handel, 1986; Jayaratne, 1987; McConeghy, 1985, 1987).

Three themes emerge from a reading of the literature on attitudes and gender differences in achievement and participation in mathematics. First, students who express a positive attitude toward their own abilities in mathematics [*confidence*] are more likely to continue in mathematics courses. Second, the perception of mathematics as useful or needed for future success [*usefulness*] is critical to the continuation of mathematical study. Finally, the positive influence of significant others, whether teachers, parents, or peers, is necessary to maintain the desire to pursue mathematics at increasingly higher levels and, for females, to overcome feelings of being "unfeminine" [*sex-role congruency*] (Armstrong 1985; Meyer & Koehler, 1990).

How girls and boys differ in their attitudes towards mathematics, and towards themselves as learners of mathematics, has received significant attention in the literature on gender differences. In a study of high-achieving students enrolled in AP Calculus courses, Casserly (1980) found that girls cited the encouragement of other high-achieving females as the most significant influence on their decisions to pursue mathematical study. Eccles, et al. (1985) found attitude was affected more often and more strongly by grade than by gender, and that time in school, coupled with grade history, had a negative effect on attitude toward learning mathematics for students of both genders. However, in the same study, boys were more likely than girls to report that mathematics is not too difficult, rated their own ability higher, claimed to exert less effort, had greater expectations of success, and were more likely to consider mathematics useful; these findings are consistent with other research (Fennema & Sherman, 1977, 1978; Joffe & Foxman, 1986; Shuard, 1986). It is significant, however, that girls typically *underrate* their success, and do better than they expect, while boys typically *overrate* their success, and do more poorly than expected (Joffe & Foxman, 1986). This discrepancy demonstrates both differences in girls' and boys' understandings of sex-appropriate responses and the problems inherent in drawing conclusions from self-reported data.

In an early study of the relationship between attitude and performance, Fennema and Sherman (1977) found that controlling for various affective measures eliminated sex-related differences in mathematics achievement. Likewise, controlling for future intent, that is, the intention to enroll in mathematics courses in the future, eliminated sex-related differences in achievement. Fox, Brody, and Tobin (1985), in a study of mathematically able students, found that

> boys and girls . . . . are more alike than different with respect to attitudes and interests. It appears that the younger generation of mathematically gifted girls have more positive perceptions of the importance of studying mathematics than past generation of gifted girls. (p. 274)

In a study encompassing a wide range of grade levels, from elementary school to college, John Ernest (1976) reported no sex-related differences in claims to like mathematics at any grade level; mathematics was the only subject studied for which no sex-related differences were found. Four subjects were considered in Ernest's study: mathematics, English/reading, science and social studies. Girls reported liking English more than boys, and boys selected science, and to a lesser degree social studies, as a favored subject more often than girls. These findings cast doubt on the power of attitudinal differences to explain differences in the performance of girls and boys in mathematics, although the importance of a positive attitude toward mathematics for success in learning cannot be discounted.

One sex-related difference in attitude which has been noted in various studies is attribution of success/failure, that is, the reason students give for good/poor performance on mathematical tasks. Four attributions are possible, *ability*, *effort*, *task difficulty* and *luck*; they are categorized as internal [ability and effort] and external [task difficulty and luck] or as stable [ability and task difficulty] and unstable [effort and luck] (Meyer & Koehler, 1990). It is commonly accepted that females are more likely to attribute success to effort and males to attribute success to ability (Fennema, 1985; Fennema, Wolleat, and Pedro, 1979; Gitelson, Petersen, & Tobin-Richards, 1982; Kloosterman, 1990; Koehler, 1990; Leder, 1984; Meyer and Koehler, 1990; Pedro, Wolleat, Fennema, & Becker, 1981; Wolleat, Pedro, Becker, & Fennema, 1980).

In a related study of the mathematical attitudes of college mathematics teachers, Taylor (1990) reported that success in mathematics was most often attributed to effort rather than ability. While the differences between the college teachers and school-aged students preclude direct comparisons, it is interesting to note that an attribution generally invoked in the academic literature as hindering the future participation of female high school students, success due to effort rather than ability, is articulated by individuals who have, by some measure at least, risen to the top levels of mathematical attainment. While these professors of mathematics were able to concede high ability to colleagues they, like Sir Isaac Newton, found the roots of their own success in "persistence and hard work" (p. 56), components of effort.

The notion that success in mathematics is due to effort on the part of the learner stems, at least in part, from early schooling experiences. The traditional curriculum, with its focus on computational competence, emphasizes this aspect of mathematics over others; during this time in school, the mathematical performance of girls is generally found to be equal to or slightly better than that of boys, particularly in computation. Shuard (1986) states that "the majority of primary teachers [privilege] the skills of computation, at which more girls do well" (p. 34) over other skills, such as problem solving, at which more boys excel. Walden and Walkerdine (1986) argue that early identification with the teacher, and acceptance of the teacher's values, allows for girls to adopt positions of relative power in the classroom, as "*sub-teacher*."

> By being positioned like the teacher and sharing her authority, girls are enabled to be both *feminine* and *clever*; it gives them considerable kudos and helps their attainment. (p. 125)

In later grades, as the emphasis on computation decreases and the ability to "break set," or step outside the accepted rules, becomes more important, the performance of girls begins to fall behind that of boys.

> To challenge the rules of mathematics discourse [which is often necessary in solving complex mathematical problems] is to challenge the

> authority of the teacher. . . . If there are considerable pressures specifically on girls to behave well and responsibly, and to work hard, it may well prove more than they can bear to break rules. . . . Our analysis leads to the conclusion that there are problems for girls, but *not* of the order of a fundamental or essential lack of ability, or of missing out on a natural sequence of correct development towards cognitive maturity. Rather, social and psychic relations coalesce to produce possibilities, positions and constraints which both allow and prevent certain forms of behaviour and of thinking. (pp. 126-127)

The conclusion that school experiences favor the mathematical achievement of boys over that of girls due to preferential treatment by teachers is certainly open to suspicion. Eccles, et al. (1985) found that the majority of teachers play a passive role in the socialization processes of their female and male students in relation to mathematics. Likewise, Shuard (1986) compared the content of test items for which a significant gender difference was demonstrated to the content of mathematics lessons:

> The *questions at which girls did better were more emphasized in the work which the children do in class*. . . . The hypothesis that the primary mathematics curriculum favours boys does not seem to be well supported by this evidence. . . . It would be mischievous to suggest that pupils who pay attention to the teacher's traditional emphases in primary mathematics give themselves a positive *dis*advantage for future success in mathematics, but the evidence seems to point in this direction.[11] (p. 31)

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[11]This quotation points to a further problem for research in mathematics education: the break between elementary and secondary teaching. Occurring at about the same time that gender differences emerge, this break in the curriculum is manifested by a shift from concrete and procedural to abstract and relational and to be successful

Shuard's analysis of the gendered nature of schooling highlights the complexity of relationships and interactions in classrooms between students, teachers, and curricula, a complexity which continues to perplex researchers in the field. Ethington (1992) points to the problems and dangers of this research:

> The patterns of influences seen through this [research] . . . emphasize the complexity of psychological influences on achievement outcomes. Influences are not always direct and readily apparent. (p. 180)

The difficulties that must be faced in determining the direction and degree of teacher impact on mathematical attitude are further complicated by social stereotyping of mathematics as a male domain (Boswell, 1985; Eccles, et al., 1985; Fennema & Sherman, 1977; Grambs & Waetjen, 1975; Leder, 1986; Northam, 1986).

This difficulty is analogous to that faced by those seeking an unchanging biological basis for sex-related differences in mathematics, namely, disentangling cultural influences outside school from those within school. Researchers have acknowledged that they ignore broader cultural impacts on the mathematics classroom and they admit the underlying assumption: that mathematical attitudes are developed primarily in the mathematics

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students must be able to make this break as well. By listening well (and being positioned as sub-teacher) in the elementary school classroom, there is some evidence that girls are less able than boys to effect this switch on entering secondary school.

classroom (Fennema, 1990). The implications of this assumption are explored below.

Defining Equity in Mathematics Education

As interest grew and the number of studies increased and the complexity of the problem was grasped more fully, one central question emerged early in the 1980s. Defining equity in relation to mathematics education was and is seen as critical in determining a proper course of action for its achievement, for how one defines equity will determines acceptable routes to achieving a equitable mathematics education for students of both genders. If there are no significant differences in the ability of females and males to learn mathematics, then the education of girls and boys should be identical. If, however, basic differences exist then the education that students receive must be adapted to meet those gender differences if equity is to be attained.

Throughout the 1970s and 1980s, numerous variables were introduced in an effort to explain and alter patterns of course-taking and occupational choice that divided along gender lines. Researchers examined the influence of parents on the mathematical achievement of girls and boys, looked at how patterns of achievement varied with age, and examined differences in the classroom interactions of girls and boys (including the effects of competitive and cooperative environments on the achievement of gender groups) as well as noting affective differences, and differences in attributions of success and failure. Research teams found that girls received less attention from teachers in mathematics classes; they are asked fewer questions, and a smaller percentage of those questions that are asked call for higher-level thinking. Girls are less likely than boys to receive either praise or criticism for their mathematical work, and what praise is given most often reflects standards of neatness or evidence of hard work (Fennema & Peterson, 1987).

But the central goal which drives this research is not the mere articulation of the nature and extent of sex-linked differences. The fundamental force that drives this research is the need to direct, shape, and control educational experiences so that females attain and achieve at the same levels as males. Elizabeth Fennema (1990) gives three definitions of equity that may be used to determine whether or not equity has been attained for females and males in mathematics education. The first, *equal opportunity*, is based on whether girls have the same opportunity to pursue mathematics as boys. Since course placements are not overtly determined by gender in the United States, equal opportunity, in its crudest sense, has been achieved. However, as Fennema argues, available data on actual patterns of course selection show a "clear difference by sex" (p. 3), which leads her to conclude that equality of opportunity is not a sufficient indication that equity has been achieved. Although equal opportunity is clearly a first step on the road to equity, alone it cannot ensure equity.

The second definition of equity, *equal treatment*, would require that all students be treated identically in the classroom. Research has documented differential patterns of treatment for female and male students in mathematics classrooms, but the relationship between teacher treatment, student achievement, and gender-related differences is unclear. As Fennema (1990) notes, "many writers have inferred or even stated that if this differential treatment were eliminated, then equity in mathematics education would be achieved" (p. 4), either because they see equal treatment as a desirable outcome in itself, or because they believe that equal treatment would eliminate gender-related differences in achievement. However, Fennema rejects equal treatment as the criterion for evaluating equity because of the uncertainty of its relationship to student achievement and to gender. Selecting equal treatment as the criterion for determining if equity has been achieved assumes that females and males will respond identically to identical educational experiences (as well as assuming that identical treatment is possible), an assumption researchers have been unwilling to make, in light of evidence to the contrary.

The final definition, *equal outcomes*, measures the degree to which equity has been attained in mathematics education by the difference in "the attainment of important educational outcomes" (p. 4) for females and males. If this definition is used, then clearly equity has not been achieved in mathematics education, for girls and women take less mathematics, report less confidence in their mathematical abilities, do not see mathematics as useful to the degree that boys and men do, and are less likely to enter mathematics-related occupations.

The goal of *equal outcomes* has been selected by Fennema over *equal opportunity* and *equal treatment* as the only choice that can rectify significant differences between females and males should they exist. This insistence on equal outcomes for females and males has led researchers to focus on the mathematics classroom and its impact on society, a one-way analysis of the relationship. Since the actions and attitudes of social actors are not containable or controllable, and those of school personnel presumably are, the discourse has centered on impacting outcomes by designing and implementing appropriate interventions for the classroom to bring about equity for females.

The selection of equal outcomes as the criterion for determining if equity has been achieved, unlike equal opportunity or equal treatment, allows for the possibility of sex-linked differences in mathematical ability and the means for addressing those differences. Although the notion that males are inherently superior in mathematics is given little credence by most researchers, males seem to perform better on many tasks that are deemed visuo-spatial in nature.[12] The relationship between such abilities as mentally rotating, folding, and completing figures to mathematical ability and achievement is at best ambiguous, as is the relationship between observed differences in performance and inherent biological differences. But the selection of equal outcomes as the fundamental goal provides teachers and researchers with theoretical and practical avenues to redress any fundamental sex-linked differences, should they exist, in the classroom.

We Gotta *Do* Something! Designing Intervention Strategies for Mathematics Classrooms

Even as researchers argue about the definitions of equity and the criteria for determining if equity for females has been achieved, the way in which these

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[12]For the most part, such "tasks" are quite contrived, and there is no consensus that they actually measure what is termed "visual-spatialization" ability.

questions are framed has profound implications for all research of the first generation. By limiting their studies to the classroom, these researchers are forced to locate both the problems and the solutions of sex-related differences in mathematics in schools. While classroom-based research has contributed substantially to understandings of gender, this narrow focus severely hampers the efforts of researchers to attain equity.

While researchers admit that gender-related differences in learning mathematics are certainly influenced by the attitudes and beliefs of the wider society, the assumption that the classroom is the location of virtually all mathematics learning, and of socialization toward mathematics, underpins the research of the first generation. Chipman and Thomas (1985) underscore this belief: "Rarely is mathematical knowledge acquired anywhere else" (p. 275); for the most part, researchers agree and extend this statement to include not only mathematical knowledge, but mathematical attitudes as well. This assumption is necessitated by the definition of equity as equal outcomes; the only location accessible to direct control is the classroom.

In the last two decades, numerous intervention strategies have been designed, implemented, and evaluated in light of their success in changing the patterns of women's and girls' participation and achievement in mathematics. The faith that these researchers place in classroom intervention is grounded in the belief that educators have the power to change schools, and thus society, and to bring about equity (Fennema, 1981, 1984).

A wide variety of interventions programs have been developed and tested, with many different specific foci for change. Many studies have pointed to the need for providing students with career information in junior and senior high school that points to the need for mathematics courses (Armstrong, 1985; Brody & Fox, 1980; Brush, 1985; Eccles, et al., 1985; Sells, 1980; Stallings, 1985; Tobin & Fox, 1980), and providing similar information to parents and other significant adults (Brush, 1985; Fennema, et al., 1981; Sells, 1980; Stallings, 1985). Other studies have highlighted the need for female role models (Brody & Fox, 1980; Stallings, 1985), for changing the atmosphere of the classroom so that female students are more comfortable (Armstrong, 1985; Burton & Townsend, 1986; MacDonald, 1980; Brush, 1985; Stallings, 1985), or altering the context or content of instruction to make mathematics more "girl-friendly" (Burton & Townsend, 1986; Eccles, et al., 1985). Finally, other researchers have recommended that attitudes toward mathematics be an explicit part of classroom discussions (Burton & Townsend, 1986; Fennema, et al., 1981) or that all students be required to take four years of mathematics in high school (Brush, 1985).

The successful intervention is fundamental to the project of these researchers. By actually changing the achievement and participation patterns of females to match those of males, researchers hope to establish firmly that the abilities of women are equal to those of men. Although rejected as a research variable, questions regarding ability are latent in this work. Explicitly, the question of ability has been dismissed; in light of the lack of accepted evidence of inherent difference in ability, researchers have correctly (in my view) abandoned biological determinism for other, more tenable, theories. But implicitly, for many, there remains the fear that such a difference may be found to exist. Achievement, then, becomes more than an alternative variable, easier to research, but the vehicle for confirming equal ability.

The central goal of these interventions, then, is not to *achieve* equality for women, but to *prove* equality of women. In 1980, researchers Camilla Benbow and Julian Stanley argued that it is differential ability that produces differential achievement. Published in *Science* in December 1980, "Sex Differences in Mathematical Ability: Fact or Artifact?" was widely-read; the conclusions of the authors regarding differences of ability reinforced female inferiority in the minds of the citizenry.[13] But research conclusions do not necessarily have to match those of Benbow and Stanley to reinforce this notion generally. Although *academics* are careful to avoid discussions of ability, those not associated with research procedures may focus on the *implicit* nature of the research project. Indeed, they may wonder, why would so much time, money, and expertise be expended to establish equal ability in mathematics via changes in participation and achievement if there were no reason to suspect that ability varies by gender? Likewise, the recent media popularization of the report of the American Association of University Women (1992), *How Schools Shortchange Girls*, serves to entrench the notion that females are inferior in mathematics and science. Although the contents of the document do not suggest any inherent deficiency, the reduction of the report in the media to a brief statement may suggest to the nonacademic that girls are in need of more intensive attention to rectify some "natural" inability.

While I have no desire to suggest that interventions or difference research are responsible for commonly-held attitudes regarding the abilities of females in mathematics, there is cause for concern that such

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[13]The relationship between the public image of mathematics, the scholar's image of mathematics, and gender will be explored in chapter 4.

investigations contribute to the continuation and entrenchment of these attitudes.

> It may be that the very vigor of this research activity has given rise to . . . the new mythology: that is, [that] males and females are basically different in cognitive and psychological makeup. (Burton, 1981, p. 106)

The history of mathematics is rich with specific examples of women's ability, but it is also permeated with the notion of the general mathematical inability of women. We must caution ourselves against assisting the survival of this out-dated notion, even though our intentions may be directed at its demise.

The primary difficulty with intervention is the implied use of force to attain equal outcomes. Intervention strategies are developed with the explicit intent of shaping the choices of young women to conform more closely with the definition of equity selected by the researcher. The process of intervention, then, becomes a way to control women by controlling their educational and occupational choices. One of the forces motivating this desire to control will be explored in the next chapter.

First generation feminists have made significant strides forward and have contributed a wealth of information to understanding the nature and extent of differences between females and males in learning mathematics in a short period of time. However, the problematic assumptions inherent in this work must be addressed if the goal of equity for all students of mathematics is to be realized.

The work of these researchers has focussed on comparisons of females to a masculine norm and, in the liberal tradition, have set equal outcomes between females and males as the fundamental aim of mathematics education. But more is involved than merely changing the educational and occupational choices of women; to gain an understanding of this, it is necessary to step further back in time and to look outside the mathematics classroom.

CHAPTER 3

HISTORICAL TRACINGS: THE ENGENDERING OF TECHNOLOGY

> The ultimate objective is to raise technology to its proper place within the context of early American history. It belongs very close to the center as an expression and a fulfillment of the American experience. (Hindle, 1966, p. 28)

> For the better part of its cultural life, the United States has been idealized as the land of practicality, the land of know-how, the land of Yankee ingenuity. No country on earth has been so much in the sway of the technological order or so proud of its involvement in it. Doctors and engineers are central to our culture; poets and artists live on the fringes.
>
> If practicality and know-how and willingness to get your hands dirty down there with the least of them are signatures of the true American, then we have been systematically training slightly more than half of our population to be un-American. . . . We have trained our women to opt out of the technological order as much as we have trained our men to opt into it. (Cowen, 1979/1991, p. 302)

> The concept of progress acts as a protective mechanism to shield us from the terrors of the future. (Herbert, 1965, p. 316)

> What matters most is the aspiration to live in balance with nature, "walk lightly on the land," treat the earth as a mother. No surprise that to such a morality most industrial processes, work schedules, and products are suspect! Who would use an earth-mover on his own mother? (Callenbach, 1975, p. 32)

The launch of Sputnik I, the first artificial Earth-orbiting satellite, helped to initiate a crisis in mathematics and science education from which these fields have yet to fully emerge. The launch extended popular perception of the scope of the Communist threat beyond nuclear attack to our technological obsolescence; increasing the level of participation of students in mathematics and science education came forth as the popular solution.

One consequence of the Soviet launch was the beginning of a long parade of widely-touted reform movements in mathematics education designed to increase participation, perhaps the most dubious of which was *new math*. New math was succeeded by other reform efforts, most recently that presented by *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 1989) and *Professional Teaching Standards for School Mathematics* (NCTM, 1991d). Each of these reform efforts has presented (and continues to present) meeting the challenges of the technological crisis as a preeminent problem of mathematics education.

The historical sketch of reform in mathematics education presented here is designed to provide a framework to examine the widespread interest and ambiguous intent that has developed around gender differences in mathematics learning discussed in the previous chapter. This historical grounding is critical, for not only has this period marked a dramatic increase in concern over education in general, and mathematics education in particular, it also has seen the re-emergence of the feminist movement, and widespread popular and academic interest in questions of gender, class, and race. The intersection of these two events, the technological crisis and the women's movement, sparked the development of interest in the field of gender and mathematics education to the degree that the relevant literature has become an almost unintelligible mountain of words -- contradictory and confusing.

The view presented in this section will assist in our understanding of how the current questions in mathematics and gender have been influenced, both presently and historically, by educational and cultural fears about technological obsolescence. Much of the effort expended toward developing gender-equitable mathematics education stems not from a desire to overcome oppression or to be egalitarian but from a cultural need to remain on the cutting edge of technology. It is assumed that this need can be met only by increasing the body[1] of mathematicians and scientists devoted to maintaining our technological position in the world. In this century, the United States has emerged as the preeminent technological power, partly

[1]The use of this word is ironic in that women, historically identified with the body as opposed to the intellect, have been appropriated as the protectors of America's technological future.

in response to the dire insult to our national pride dealt by the Soviet launch in 1957; our sense of being, as defined by government, corporate and intellectual leaders, is based on the belief in power through technological superiority. The discourse of "superiority in-and-by technology" is grounded in the same discourse that looks for the basis of female inferiority in mathematics. That the path to gender equity in mathematics is found by many in technological involvement is both significant and disturbing.

This chapter examines the relationship between society, technology, and gender. "The belief in the inevitability of progress and of progress precisely as technological progress" (Segal, 1985, p. 1) has been a defining feature of the culture of the United States since its creation, and a feature of American utopianism since the late 1800s. David Orr (1992) notes that "any decent philosophy of technology will be a political philosophy that clarifies the effects of technology on the distribution of *power* and *control* in society" (p. 40; italics added). Therefore, such a philosophy of technology must address itself to a critical understanding of gender. As a challenge to the prevailing attitudes of Americans who are "technological somnambulists wandering through an extended dream" (Winner, 1986, p. 169), I will look to the concerns of feminists and other theorists regarding gender bias in the history of technological development, and to the gendered nature of technology itself.

This investigation will allow a re-presentation of technology and technological education as a gendered and engendering construct that raises difficult problematics for those interested in gender-equitable mathematics education. I conclude that in our refusal to ask ourselves these difficult, and perhaps unanswerable, questions about mathematics and gender, and in our compliance with the demands of business and industry for technological advances, we have relinquished control over our research; we have allowed the needs and desires of technological progress to determine our research agenda and, thereby, our conclusions.

Although much of this chapter will focus on problems and critiques of the technological mindset so characteristic of American culture, this is not to be interpreted as a rejection of technology. To do so, as I type this into the memory of my computer, would be profoundly hypocritical. Rather, I am addressing the "ideology of technological society" (Rothman, 1989, p. 49) with its "consistent theme . . . of order, productivity, rationality and control" (p. 52) that provides "mechanical/industrial metaphors for *everything* (p. 49).

The Technological Roots of the United States

The promise of advancement through technology has been a prominent part of the American consciousness since the American Revolution. Developments in printing and in the manufacturing of weapons were central to the victory over the British Empire; many of the "founding fathers," most notably Franklin, Jefferson, and Washington, were committed to "ushering in a new scientific and technological era . . . [that] would help to free the people of young America from economic subjugation to Europe" (Oliver, 1956, p. 104). Thomas Jefferson in particular grounded his hopes for the promotion of the general welfare in the promises of science and technology.

In the years that followed, technological innovations and the abundant resources of the new country contributed to the feeling that "the nation could create and sustain virtually limitless growth" (Marcus and Segal, 1989, p. 52); historian of technology Brooke Handle (1966) states that technology has been "an expression and a fulfillment of the American experience" (p. 28) throughout our history. Unlike some Europeans of this era, Americans generally did not engage in widespread protest or exhibit great concern about the introduction of machinery into industry, but welcomed it instead as "the one thing needful to furnish the freedom and leisure necessary for intellectual exercises" (Walker, 1831 [cited in Marcus & Segal, 1989, p. 84]).

In his commentary on America, Alexis de Tocqueville (1840/1945) surveyed the place of technology in the common consciousness:

> In minds thus predisposed [to technological innovation], every new method that leads by a shorter route to wealth, every machine that spares labor, every instrument that diminishes the cost of production, every discovery that facilitates pleasures or augments them, seems to be the grandest effort of the human intellect. (p. 45)

Such faith is not uncommon in the United States. Our current commitment to technology can be traced back, at least in part, to the innovations of Industrial Europe (Segal, 1985), and, in the late 19th and early 20th centuries, utopian theories and reform movements alike converged on the power of technology to ease burdens and eliminate want. Although unable to test their theories about building a utopian society, the writings of a small group of *technological utopians* were "widely and warmly received" in a culture partial to "the gospel of progress and of progress as technological progress" (Segal, 1985, p. 102). Although not long-lived as a philosophical and social movement, the technological utopians contribute significantly to contemporary attitudes toward the benefits of technological innovation, increasing our collective faith in the power of technology as a positive social force.

In the years that followed, technology became more firmly entrenched in the American consciousness as innovations emerged in the fields of transportation, agriculture, communication, energy, entertainment, warfare and in the home. The end result was the rise of the United States to the status of world power, based primarily on the industrial power developed in the late nineteenth and early twentieth centuries, and the outbreak of war in Europe in 1917 (Oliver, 1956). Throughout the history of the United States "technology has been an integral facet of American experience" (Marcus & Segal, 1989, p. 361). While the specific technologies themselves have evolved, disappeared or come into being, the promise of a better life through technological advancements and the faith of the American people in that promise has grown.

Sputnik and the Emergence of Crisis

At the end of World War II, the United States basked in the glow of a decisive win and, in the decades that followed, Americans continued to accustom themselves to the luxuries, necessities, and inevitabilities of technological innovation. Magazine pages of the late 1950s and early 1960s were filled with advertisements extolling the latest products; the "good citizens" depicted in these ads installed the newest home technology to make life easier, built bomb shelters to make life safer, and traded for current model-year automobiles to keep up with the pace of modern life.

But the confidence of Americans in the technological superiority of the United States suffered a stinging blow on October 4, 1957, when the Union of Soviet Socialist Republics launched Sputnik I, and the world entered the Space Age with the Bear in the lead.[2] As Magyar (1961) said:

> Ever since the Russians launched their Sputnik, gloom has descended on the American Horizon. Public opinion, aroused by this event, found a ready answer to the complaint that we had failed to train enough scientists and technicians. The fundamental cause of our suddenly discovered inferiority was . . . our educational system. (p. 293)

Already concerned with a lack of "manpower" in scientific and technological arenas (Cooper, 1985a, p. 128), the countries of the West stepped up efforts to reform mathematics and science education. Both this concern and the activity that followed were intensified by the public's fear of Communism and fueled by the release, at least in the United States, of massive public funds for reform (Moon, 1986; Kliebard, 1987). The express scientific and technological purposes behind this release

[2]The launch of Sputnik I was followed one month later by the launch of Sputnik II, which carried a dog into space. Another month later, an attempt to launch a American satellite failed.

of funds were revealed in the first paragraph of the National Defense Education Act of 1958:

> The Congress hereby finds and declares that the security of the Nation requires the fullest development of the mental resources and technical skills of its young men and women. The present emergency demands that additional and more adequate educational opportunities be made available. The defense of this Nation depends upon the mastery of modern techniques developed from complex scientific principles. (Kliebard, 1987, p. 266)

Prior to Sputnik, mathematics educators in the United States had already been engaged in developing programs to meet "the needs of society [and] . . . the needs and characteristics of the pupil" (Kinney and Purdy, 1952, p. 31). Following passage of the National Defense Education Act in 1958, the majority of programs benefitting from the largess of Congress were focused on "modern" mathematics, or "new math." Arguing that the mathematics currently taught in school "hadn't changed in the last 300 years" (Sharp, 1964, p. 11), reformers in mathematics education escalated their efforts to reshape the content of the mathematics curriculum to reflect the growth that had occurred in mathematical knowledge. This modern curriculum, it was believed, would allow students to meet the needs of a constantly changing, technological world.

In his history of curriculum, Herbert Kliebard (1987) emphasizes that these reform efforts were not controlled by the education community, but by the mathematicians and scientists who were the recipients of the bulk of newly-available federal funds. He writes:

> Almost without exception, the directors of these major [curriculum revision] projects were drawn from academic departments in major universities. Control of curriculum change . . . had reverted from its traditional locus in the professional education community to specialists in the academic disciplines. . . . The longstanding emphasis on local efforts at curriculum change was replaced by a pattern of centrally controlled curriculum revision. . . . The process of curriculum change [became] one in which the curriculum would be developed first by experts at a center set up for that purpose with the local school systems perceived as consumers of external initiatives. (p. 268)

Concern about technological progress and the loss of world preeminence following Sputnik supported the efforts of academic specialists to gain control over curriculum revision. To quote Kliebard (1987):

> Life adjustment education was already in steep decline when . . . Sputnik . . . was launched by the Soviet Union. . . . Quickly, life adjustment education was seen as the prime example of America's "soft" education in contrast to the rigorous Soviet system. While American schoolchildren were learning how to get along with their peers or how to bake a cherry pie, so the explanation went, Soviet children were being steeped in the hard sciences and mathematics needed to win the technological race that had become the centerpiece of the Cold War. (pp. 264-265)

One result of the end of life adjustment education was a re-entrenchment of the academic subjects as the basic components of education, and a fostering of distrust of educators who had given the country a weak and ineffective education system.

The "technological race" that Kliebard mentions did not end with the launch of Sputnik; rather, the launch of Sputnik can be seen as the herald of technological marvels to come. The success of the Union of Soviet Socialist Republics reminded the United States that the competition for preeminence did not have a guaranteed outcome: complete dedication to innovation was needed if the United States was to emerge the victor. It became a matter central to national pride that the first person to set foot on the moon be a citizen of the United States.

Great emphasis was placed on the education of the "best and brightest" students during this period. Hyman G. Rickover, Vice Admiral of the U. S. Navy, argued that the degeneration of American education was the result of equality gone awry; this misguided sense of equality had allowed talented American students to go without proper education (Rickover, 1959), particularly in comparison to the countries of Europe (Rickover, 1962, 1963). Although future developments turned the attention of some educators in other directions, concern about students who are thought to have the most to offer society has formed a lasting undercurrent in educational circles, particularly in mathematics education. In regard to the technological crisis, it has been to the identification and retention of precisely these students, in general as well as specifically female and minority students, that current reform efforts are being addressed (NCTM, 1986, 1989, 1990). In relation to gender, such differentiations have their roots in theories of masculine superiority (Cooper, 1985b).

Changes in Mathematics Pedagogy

In the late 1950s and early 1960s the school population in the United States was growing both as the general population increased and as more students stayed in school through graduation (Philadelphia Suburban School Study Council, 1964). In addition to growing larger, the demographics of schools were also changing as the gains made by supporters of integration, beginning with *Brown v Board of Education of Topeka, Kansas* in 1954, were implemented (Howes, 1970b).

The launch of Sputnik, and the availability of funds that it triggered, had contributed to concern about both kinds of exceptional students, those identified as talented as well as those considered "underprivileged" (Griffiths and Howson, 1974, p. 138). Initially, most effort had been devoted to the mathematics education of talented students; the result of this emphasis was the rise of ability grouping. Students grouped by ability, it was thought, would receive an education specifically tailored to their needs and the needs of others like them. As the demographics of the school population, as well as the tenor of public discourse surrounding the education of minority children, changed, more attention was given in the literature to identifying and separating "disadvantaged" students from other students, determining the needs of such students, and meeting those needs in the mathematics classroom (Mintz, 1968; Pflaum, 1968; Sobel, 1967; Stovall, 1968; Troisi, 1968). However, a few argued that good mathematics education for all students would also meet the needs of "non-achievers" and "culturally disadvantaged" students (Davis, 1967, p. 12). It was argued that special attention for these mostly minority and/or urban students was not necessary provided that the goal of good mathematics education for all was realized.

In this attempt to provide a strong education for all students, considerable effort was devoted to exploring the classroom practices and theoretical assumptions surrounding grouping students by ability. A practice that had been gaining momentum since the 1930s (DeHaan & Doll, 1964), ability grouping was the most commonly-used method of grouping students to maximize achievement (Weaver, 1961) and, in the 1960s, it increasingly came under attack by educational theorists and researchers. Groups of students arranged homogeneously by ability as defined by one standard, it was argued (Goodlad and Anderson, 1959; Weaver, 1961), were certainly heterogeneously grouped by any other standard. Goodlad and Anderson (1959) add:

> The greatest variation occurs, usually, for children at the top and bottom of the achievement continuum. And yet, paradoxically, when grouping by ability levels is proposed in educational circles, it is invariably the gifted or the slow who are to be segregated into "homogeneous" groups (p. 15).

Concerns about the problems of creating homogeneous groups of students led away from strict reliance on academic ability to plans for grouping students in other ways. Additional motivation for moving away from creating homogeneous classes was provided by the worry that ability grouping contributed to a "wastage of talent" among students of "lower ability" (Kelly, 1978, p. 10) by denying them contact with their more able peers. Concern with waste hastened the move to find ways of differentiating methods, assignments, and rates of progress (Goodlad and Anderson, 1959; Melby, et al., 1964; Howes, 1970b; Duker, 1972) in order to provide better educational outcomes for all students.

As educators probed the problems of ability grouping, the importance of individual differences crystallized. Many in the education community embraced individualized instruction as the pedagogic key to reaching masses of students who were failing or rejecting mathematics courses. The period from the mid-1960s to the late 1970s showed an increase in the number of educators proclaiming the virtues of an individualized mathematics program which would not only allow for differences in learning rates, but allow students to pursue "personal investigations . . . which develop from problems children face as they explore the environment" (Howes, 1970a, p. v).

Schools were criticized for disregarding differences among learners and perpetuating practices that "accentuate rather that alleviate individual differences" (Duker, 1972, p. 20). In the literature on individualized instruction, numerous differences in student ability and preparedness are highlighted: parental involvement, prior school experiences, participation in Head Start programs, military service of parent(s), sibling rank, maturity of student, personal health, and social status[3] (West & Doll, 1964; Keuscher, 1970; Duker, 1972). Left unaddressed, such differences grow larger rather than smaller as time spent in school increases (Thomas & Thomas, 1965). In order to individualize instruction, "ways to permit the student to progress at *his* rate according to *his* style of learning and ways to motivate *him* to think creatively in formulating his mathematical concepts and knowledge of mathematics" had to be developed (Gibb, 1972, p. 394; italics added).

Historically, the curriculum differentiated by ability has also been differentiated by gender, race, and

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[3]It is interesting to note that each of these lists fails to include categories of gender or race. However, the current discourse on gender has taken up the fight to eliminate the waste of talent in mathematics.

social class (Cooper, 1985b; Kliebard, 1987). The challenge sounded by the opponents of ability grouping resonated first with the struggles of black Americans, and later with those of women. By rejecting ability grouping, educators were able to embrace a theory of education that proposed to deliver the best possible education for each individual student. In this view, the rejection of differentiation by ability results in a less discriminatory presentation of mathematics curricula.

A strong undercurrent in the tension over grouping patterns is *waste*, a legacy of social efficiency theory in education (Kliebard, 1987). On the one hand, teaching all students in the same way eliminates the waste of preparing multiple lessons and goals; educators need only expend their energies to find and deliver the best possible instruction. In such a system, all students are treated identically, and students are grouped by ability to facilitate identical treatment. On the other hand, teaching students in the manner which is best for each of them can be seen as less wasteful, for each student gets the maximum benefit from school, and can contribute her/his best to society. In this system, students are given the education which best suits them and, since individual needs and abilities vary, instruction (and perhaps curriculum) is varied to meet the needs and develop the abilities of every student. Since each student is necessarily different, there is no need to attempt to group students by ability.

Although committed to individualization at the theoretical level, educators found that developing and implementing a curriculum that is completely individualized is a difficult goal to reach at the level of classroom practice. A variety of ways to individualize instruction were proposed: nongraded schools, departmentalization, teacher-student contracting, Individually Prescribed Instruction [IPI], and computer-assisted instruction [CAI] (Goodlad, 1959; Howes, 1970; NCTM, 1970; Gibb, 1972). These last two, IPI and CAI, were promoted as both highly individualized and efficient: students progress at different rates, receiving appropriate instruction, assignments, feedback, diagnosis, and remediation automatically.

Technology and Mathematics Education

Even as educators were moving from ability grouping towards a recognition that "all teaching . . . is mixed ability teaching" (Ridley, 1982, p. 37), meeting the demands of living in a technological world remained central. The educational system "must be productive of adaptable citizens" (Kelly, 1978, p. 23) who can live with today's technology as well as accept that such technology is already moving toward obsolescence.

One outstanding feature of the discourse on individualized instruction is the belief in the potential of the electronic digital computer as the vehicle for realizing truly individualized instruction (Darnowski, 1970; Suppes, 1970). In this case, the power of the computer lay in its ability to record and respond to student errors rapidly, and to supply pre-programmed instructional tasks to rectify those errors, all without the intervention of the teacher. Unfortunately, the difficulties and expenses involved in bringing computers into every classroom, or even into every mathematics and science classroom, have not been overcome at the rate assumed by mathematics and science educators in the 1970s; wide-spread computer-assisted instruction is still only on its way to becoming a reality (Apple, 1988).

There are actually two representations of computer technology (which can be extended to a broader sense of technology), in the educational literature: (1) technology as a component of the curriculum and (2) technology as a device for instruction. This first sense does not refer to courses in "computer literacy," where students are taught programming. The NCTM position statement on the use of computers states that "computer programming activities in mathematics classes should be used to support mathematics instruction; they should not be the focus of instruction" (NCTM, 1987, p. 15). But technology becomes an implicit part of the curriculum when time and emphasis are allocated to certain topics or instructional modes "consistent with their importance in an age of increased access to technology" (NCTM, 1987, p. 15) and when the content of the curriculum is determined to a significant degree by technological changes and applications (NCTM, 1989).

It is to the second sense, technology as a device for instruction, that the majority of efforts have been addressed. These efforts are rooted in the belief that new skills are "necessary for adaptation to constant technological and occupational change" (Noble, 1988, 242) and that schooling should provide these skills. Indeed, there is continued belief among educators, an extension of the larger cultural faith discussed earlier, that "'high tech' . . . will save our students and teachers" (Apple, 1988, p. 291) as computers allow education to accomplish its goals more effectively and efficiently (Noble, 1988; NCTM, 1987, 1989, 1990, 1991a), including the goals of gender and racial equity. Although mathematics educators were initially reluctant to allow computer and calculator technology into the classroom for fear that students would fail to learn to perform paper-and-pencil calculations, this worry has been officially abandoned (NCTM, 1987, 1989, 1990, 1991a; National Research Council [NRC], 1989).

The sense of crisis in mathematics education that followed the launch of Sputnik re-appeared more recently in 1983 with publication of the report of the National Commission on Excellence in Education (NCEE), *A Nation At Risk*. Once again, our "preeminence in commerce, industry, science, and technological innovation" (NCEE, 1983, p. 5) was threatened by an educational system too inadequate to properly prepare students for the world in which they lived. Though now couched in fewer militaristic and more economic terms since the fall of the Union of Soviet Socialist Republics, this remains much the same crisis that emerged following Sputnik and is driven by deep-seated feelings of patriotism:

> Our children could be stragglers in a world of technology. We must not let this happen; America must not become an industrial dinosaur. We must not provide our children a 1960s education for a twenty-first century world. (Fausto-Sterling, 1985, p. 54)

One key to providing this "twenty-first century" education was the incorporation of technology. As early as 1975, participants in the National Institute of Education Conference on Basic Mathematical Skills and Learning were considering the place of technology in mathematics education. Some clutched desperately at the old ways:

> It is . . . important to have students understand how and why calculations work in order to use calculating devices correctly.

> Knowing how to calculate often tells you when to calculate by that particular process.[4]
>
> Still, calculating should be placed in proper perspective. The present rate of sale for hand-held calculators . . . suggests that computation should be taught in this form: "What if we were shipwrecked on a desert island and we wanted to . . ." (Rising, 1975, p. 152)

But the majority of positions at this conference were articulating the currently-accepted position regarding the use of calculating technology in the mathematics classroom (Armstrong, et al., 1975; Branca, et al., 1975; Buchanan, et al., 1975; Romberg, 1975). Within a few years, more and more people were listing and praising the uses and benefits of calculators and computers in the mathematics classroom (Collis, 1983; Coleman & Selby, 1983; Fitting, 1983; Kurtz, 1983; NCTM, 1978). Although not as fully developed as current recommendations and suggestions (NCTM, 1987, 1989, 1990, 1991a; NRC, 1989) in recent years, the publications of this period clearly set the stage for future positions on the place of calculators and computers in the classroom (NCTM, 1980).

Since the publication of *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), the prominence of technology in mathematics education has continued to expand (Branca, Breedlove, & King, 1992;

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[4]Given the state of students' abilities at solving word problems as compared to performing computations, the validity of this statement is dubious at best.

Burrill, 1992; Hembree & Dessart, 1992; Wheatley & Shumway, 1992).

> Technology not only has made calculation and graphing easier, it has changed the very nature of the problems important to mathematics and the methods mathematicians use to investigate them. Because technology is changing mathematics and its uses, we believe that appropriate calculators[5] should be available to all students at all times; a computer should be available in every classroom for demonstration purposes; every student should have access to a computer for individual and group work; students should learn to use the computer as a tool for processing information and performing calculations to investigate and solve problems. (NCTM, 1989, p. 8)

Because "*what* students learn is fundamentally connected with *how* students learn" (NCTM, 1991d), the introduction of calculators and computers into the classroom has clear political and economic purposes.

> The economic status quo in which factory workers work the same jobs to produce the same goods in the same manner for decades is a throwback to our industrial past. . . . Traditional notions of basic mathematical competence have been outstripped by ever-higher expectations of the skills and knowledge of workers; new methods of production demand a technologically competent workforce. (NCTM, 1989, p. 3)

Not only is technology to become a critical tool in learning mathematics, acceptance of it has become a central purpose of teaching mathematics.

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[5]This notion of appropriate calculators has been taken so seriously that Texas Instruments has developed several different calculators for students at various levels that are only available through educational suppliers. Thus, the relationship between mathematics education and the business of technology grows increasingly complex.

This brief history of educational reform highlights the centrality and magnitude of the force exerted by technological concerns. Although educators have varied widely in their approaches to education, the aim of that education is to prepare students for the ever-changing world in which they will live. Technology is more than a curriculum component or teaching tool; it has become the force that motivates reform, and the criterion by which success is measured.

Women and Technology

The attention of feminist scholars has also turned to considerations of technology and its relationship to gender. In examinations of the history of technology, feminists found that inventions and devices used or developed primarily by women were entirely absent. For example, the baby bottle, a significant and wide-spread technological device, has been one of the more controversial exports of Western technology to developing nations. This device, which alters the interactions of mothers and children, had been entirely omitted from all "standard histories of technology" (Cowen, 1979/1991).

The realization that histories of technology did not include references to female inventors or to innovations related to women's social roles led to even greater interest in the field of technology. Feminist scholars have since written about the contributions of women to technology, from ancient times (Alic, 1981; Stanley, 1981, 1983; Vare & Ptacek, 1988) to more recent events, recounting the innovations of American Shaker women in domestic and commercial technology (Irvin, 1981) and the biographies of female engineers (Trescott, 1983). Others have explored the impact of technology on household chores (Bose, Bereano, & Malloy, 1984/1991; Hoy, 1985/1991; Rothschild, 1983), on women's waged work (Arnold, Birke, & Faulkner, 1981; Feldberg & Glenn, 1983; Zimmerman, 1981), women's communication (Kramarae, 1988), and women's health and reproduction technology (Glendinning, 1990; Ratcliff, et al., 1989; Rothman, 1989).

Although women have traditionally been regarded as closer to nature than to technology, the contributions of females to technological innovation have been widespread and consistent throughout Western history. Hypatia, known primarily for her mathematical teaching in ancient Greece, also developed numerous scientific instruments, including an astrolabe, a device for distilling water and a hydrometer for determining the specific gravity of liquids (Alic, 1981). In the Middle Ages, before the science of medicine moved from the female realm into the male, female healers knew that moldy bread prevented infection, used belladonna to prevent miscarriages, and treated heart ailments with digitalis (Stanley, 1983).[6]

Of particular note is *Mothers of Invention: From the Bra to the Bomb: Forgotten Women & Their Unforgettable Ideas* (Vare & Ptacek, 1988). Authors Ethlie Ann Vare and Greg Ptacek seek to fill the void in history by detailing the contributions of female inventors, including solar heating, the drip coffeepot, refrigeration, the square-bottomed paper bag, invisible glass, usable penicillin, tract housing, the "Geiger" counter, Liquid Paper, and sediment-free champagne. In some instances, the authors also correct textbook versions of history, for example crediting Catherine Littefield Greene of Georgia with the creation, perfection, and marketing of the cotton gin; Eli Whitney, her houseguest from Massachusetts, was its builder.

Any history of technology that fails to recognize the ongoing contributions of women defines technology *a priori* as those things that men do. This male bias perpetuates the image of technology as masculine, ignores those "feminine" technologies that affect our lives, and continues to cast women as "technologically ignorant and

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[6]When medicine became the province of men, these treatments were considered "superstition"; the male physicians prescribed bleedings and incantations instead. Modern medical practice has "discovered" that penicillin can be produced from moldy bread, and derivatives of belladonna are still used as antispasmodics.

incapable" (Wajcman, 1991, p. 137). These "feminine" technologies have been fundamental in the development of human civilization and are generally located in the areas of horticulture, childcare, and food preparation (Stanley, 1981; Vare & Ptacek, 1988). Although the technological developments of women have tended to fall in the spheres of life for which women are responsible, women have made significant contributions to more "masculine" spheres like atomic physics, computer programming, and engineering (Irvin, 1981; Trescott, 1983; Vare and Ptacek, 1988).

In seeking to understand the relationship between gender and technology in contemporary culture, it is crucial that the relationship between technology and nature, and between nature and gender, be explicitly revealed. As Ynestra King (1983) observes,

> In the process of building Western industrial civilization, nature became something to be dominated, overcome, made to serve the needs of men. She was stripped of her magical powers and properties as these beliefs were relegated to the trashbin of superstition. Nature was reduced to "natural resources" to be exploited by human beings to fulfill human needs and purposes which were defined in opposition to nature. . . . With the disenchantment of nature came the conditions for unchecked scientific exploration and technological exploitation. (pp. 120-121)

Nature has changed from a living entity to be revered and respected to a resource to be managed and controlled; throughout recent history, the relationship between humans and the natural world has been one of exploitation and domination -- exploitation of female nature, domination by man. This relation of exploitation and domination has resulted in a society that is fundamentally anti-nature as well as anti-female.

The tradition of viewing nature as female is longer than that of written history; the subjugation of female nature to male forces is deeply embedded in patriarchal systems of modern thought and action. As Cynthia Cockburn (1985) states:

> Our industrial technology . . . has the imprint and the limitations that come of being both the social property and one of the formative processes of men. Industrial, commercial, military technologies, are masculine in a very historical and material sense. . . . Industry and contemporary technology both express and embody values that on the one hand developed out of patriarchy, and on the other have developed to make patriarchy what it is in modern society. The relations surrounding technology continually renew and extend male hegemony over the rest of us. (pp. 56-58)

It is crucial at this point to clarify the purpose of this critique of technology. I am not suggesting that machinery, techniques, and tools be thrown away to allow a return to some mystical, mythical, non-technological, non-sexist past, but instead that we seek to understand the "technological ideology" that defines all action in terms of making, of production. Thus,

> the critique of technology . . . is an objection to the nation of the world as a machine, the body as a machine, everything subject to hierarchical control, the world, ourselves, or bodies and our souls, ourselves and our

> children, divided, systematized, reduced. (Rothman, 1989, p. 54)

Reducing everything to something which is made, and every act to the act of making, can allow anything to become a commodity. As Barbara Katz Rothman (1989) observes:

> U. S. Court of Appeals judge, Richard Posner, . . . advocates eliminating inefficient adoption agencies and legalizing the sale of babies. What is there in our way of viewing the world, in our values, ideas, beliefs, and culture, that enables us to think of a baby as a commodity? Even if we reject it, it was a "thinkable" thought and we know what he means. (p. 51)

We do indeed know what he means as "unthinkable" as it sounds. That it is possible to put into words makes the point.

In her examination of the impact of technology on motherhood, Rothman links the technological ideology with liberal philosophy, the foundation of American political systems. Therefore, "liberal philosophy, the intellectual underpinning of the American revolution and of American government, is the articulation of the technological ideology in the social order" (p. 58). From these liberal foundations spring a number of unequal dichotomies: mind/body, mental labor/manual labor, science/nature, and male/female.

Liberalism, Feminism and Technology

Alison Jaggar (1983) identifies two tenets of liberal theory that are significant here: that rationality is a mental capacity; and that rationality is a characteristic of individual human beings, not of social groups. The first of these assumptions, that rationality is mental rather than physical, disconnects the mind from the body, emphasizing and privileging mental functions over physical ones. It is not coincidental that, historically, men have been connected more closely with the mental, and women with the physical. The second assumption, that rationality is a feature of individuals rather than of social groups, functions to disconnect human actors from the social arena in which they act, similar to the function of the mind/body dualism of the first assumption. This abstract individualism discourages the recognition that rationality is constituted or defined by group norms that are culturally specific; this failure allows liberals to present their version of abstract individualism as a universal characteristic of humanity (Bowers, 1993, p. 89). Furthermore, failing to acknowledge the cultural grounding of group norms denies the possibility of making those norms explicit and subject to group consideration, critique, and revision. The final assumption identified by Jaggar (1983), that the capacity for rationality is possessed by all human beings in approximately equal measures, universalizes one view of human nature, rendering alternative and incompatible perspectives silent and invisible.

This grounding in liberalism has several important implications for education. First, the perception of human beings as self-constituting individuals who make their own reality denies the cultural roots of thinking and knowing. Far from making something from nothing, the thoughts of an "individual" are shaped by the "thought patterns of the cultural group" (Bowers, 1993, p.89). Furthermore, by failing to recognize the relationship between cultures and individuals, liberal theorists universalize a mechanistic view of the world that is not shared by all other cultures. For instance, the modern view that progress is constant and change is inevitable is not consistent with Native American cultures that place higher value on the continual "re-enactment of traditional patterns . . . of existence" (p. 88); likewise, the notion of the autonomous individual does not mesh with a worldview that "conceives of the self not as strictly delimited or defined, but as [at most] a concentration. . . . Most of what is *other* for us is [for Native Americans] . . . identified with the self" (p. 92; italics added). The language of such groups does not permit the expression of autonomy, the separation from the social, cultural, and physical environment that is characteristic of liberalism.

The autonomous individual of liberal theory comes to know through interaction with data; the electronic computer is one means through which access to data can be increased, thereby increasing the potential for developing individual rationality. All knowledge that is worthwhile can be stored and transmitted in this form. Such a view fails to consider forms of knowledge and ways of knowing that are not reducible to data or information, such as analogical knowing; not only are these alternatives not considered as valid, they are often not realized at all.

Because rationality is a singularly human capacity, the highest value is placed "on those activities which [are] perceived as requiring the most use of reason" (Jaggar, 1983, p. 175); intellectual pursuits are favored over physical endeavors, science and mathematics over poetry and sculpture. Underlying the view of educational technology as revolutionary and emancipatory is, again, a core of liberal assumptions that go largely unnoticed. As C. A. Bowers (1993) points out in "Ideology, Educational Computing and the Moral Poverty of the Information Age," these core assumptions include the essential elements of liberalism: individual autonomy, rational empowerment through increased access to information, the linear and progressive nature of change, and anthropocentrism. The discourse of educational technology is closely bound to the ideology of liberalism, emphasizing the individual's capacity to reason and deemphasizing the relationship between the individual and the culture.

At the heart of liberal theory is the notion of equity. For liberal feminists, the capacity for rationality is not related to gender; with equal access to data, women's rational abilities can equal those of men. For contemporary liberal feminists, equity is interpreted to mean equal opportunity. To quote Jaggar (1983):

> When liberal feminists talk about opportunities . . . they mean opportunities for securing the prestige, power and (usually) wealth that are the rewards of success in industry, commerce, scholarship, the arts, entertainment, politics, or sport. . . . A predominance of men in any area is taken as evidence that opportunities in fact have not been equalized. Thus, while liberal feminist theory professes [not to know] the results of equalizing opportunities between women and men, liberal feminist practice assumes that those results can be predicted. (pp. 194-195)

Devoted to individual equality, liberal feminists struggle to equate the genders, concentrating their efforts on securing equal access and rewards through legal and educational means.

Whether opportunities are equal is determined by the degree to which outcomes are equal. In other words, if women and men have the same opportunities, the choices of women will parallel those of men. Outcomes that are not equal are seen as compelling evidence that opportunities are not equal. In mathematics, this means that if women do not achieve and participate at the same level as men then the goal of equal opportunity has not been reached.

It becomes necessary, then, to control and direct outcomes to ensure that the goal of truly equal opportunity has been reached. In mathematics education, this means that women must profess attitudes and take actions that are similar to those of men. The aim of liberal feminists then is to discover ways to control and direct the choices of women in relation to mathematics, an aim at odds with the emphasis placed on individual freedom in liberal theory:

> In its pursuit of equal opportunities, liberal feminism . . . challenges the liberal value of individual liberty. . . . In their attempts to eliminate restrictions on women's equality of opportunity, contemporary liberal feminists place heavy reliance on the action of the state. . . . However, if liberal feminists were to follow their own logic through to the end, the notion of equal opportunity could be used to justify state control of every aspect of life. . . . Equality of opportunity is incompatible with individual liberty, a value which is at least as basic as equality within the liberal tradition. (p. 195)

Education and Technology

The educational impact of the launch of Sputnik, although distant, is not yet too faint to be noticed. Although altered by the end of the Cold War, the technological crisis that it spawned is still in the forefront of the nation's consciousness. Coupled with the gains of the most recent surge in feminist activity, fears of technological obsolescence and hope in technological salvation have lead to increased interest in the mathematical participation of females. Grounded in liberalism, this discourse seeks to predict and ultimately to control the choices of women for technological ends.

In the years since Sputnik and Women's Lib, these two concerns have become deeply entwined in the goals of mathematics education. In the introduction to *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) both mathematics education for a technological world and equal opportunities for women and minority students are highlighted:

> Women and most minorities . . . are seriously underrepresented in careers using science and technology. . . . We cannot afford to have the majority of our population mathematically illiterate. Equity has become an economic necessity. (p. 4)

Concerns about gender equity in mathematics education stem from this sense of crisis in science and technology. This anxiety about our technological future has found a toehold in differences based on gender: in order to increase the number of mathematicians, scientists, and technologists, we need only increase the proportions of female and minority students in mathematics courses; the deficiencies of women have become the salvation of the country. Educational technology has been embraced both as the means for achieving gender equity and as the justification for pursuing equity in mathematics education.

A series of studies by Mary Poplin (1991) looked at "the concerns over women's underachievement (as compared to men's) in mathematical and computer pursuits" (p. 1). After identifying women with high mathematics aptitude, Poplin interviewed those who had not selected mathematical or technological careers: All were aware of the advantages, particularly financial, of mathematics- or computer-related careers. Poplin concluded from these interviews that they "[made] self-conscious and well-informed choices about not participating in math . . . [and were] not simply manipulated by society" (p. 23). She says:

> I have been convinced . . . that their disinterest is an actively constructed one [and] I am more cautious in my pronouncements that we simply must get more women into math. . . . I, like many feminists, am wondering if it would not be more profitable to strive to upgrade the status of the fields women enjoy than to try to change our ourselves and our interests to match more nearly those of men. (pp. 24-25)

Her misgivings about encouraging women to pursue the interests of men are echoed by Cynthia Cockburn (1985):

> Women are not merely failing to enter technology. On the one hand we are being repelled, and on the other we are refusing. (p. 56)

By insisting that women join the technological push, we demand that these women forget that technological innovation surged in opposition to the ultimate icon of femininity, nature. Acknowledging the legitimacy of alternative choices is grounded in the rejection of liberal notions of equality measured by outcomes.

We have accepted the crisis of Sputnik and framed our response to it: our problems, perhaps now more economic and corporate than militaristic, can be resolved through technological progress. The solution to the threat of technological obsolescence is to increase the number of technologists. As the population of schools (and society) has diversified, concerns for the mathematics education of female and other minority students have grown, not from egalitarianism, but from technological and economic necessity. As institutions of patriarchy, the needs of business and industry require that the technological participation of women be indistinguishable from that of men. Any alternative considerations or contributions that women might bring are potentially threatening to the perpetuation of technological innovation. As Bowers (1993) notes, technology is being used "to serve the interests of specific groups -- centralizing economic and political power by making the panopticon society a closer reality and by turning many work settings into 'electronic sweatshops'" (p. 85); one is forced to wonder what the nature of women's technological participation will entail.

It is into this technological crisis that research in gender and mathematics education has been subsumed. In serving the purposes of technological progress we have allowed our research questions to be determined for us. We have steered away from looking to our definition of mathematics itself, and the liberal ideology which supports it. We have been directed toward questions about the gender differences in *students*, and away from questions regarding the gendered nature of mathematics.

CHAPTER 4

JUST US GIRLS: EXPLORING THE FEMININE SIDE OF MATHEMATICS

> Mention mathematics to a woman and she freezes into a condescending attitude of tolerance--she knows it exists, she uses it when she must, but it certainly has very little to do with her own delightfully imaginative and delicate world of interests. (Weber, 1957; quoted in Sommer, 1958)

> On the eighth day, God created mathematics. He took stainless steel, and he rolled it out thin, and he made it into a fence, forty cubits high, and infinite cubits long. And on this fence, in fair capitals, he did print rules, theorems, axioms, and pointed reminders. "Invert and multiply." "The square on the hypotenuse is three decibels louder than one hand clapping." "Always do what's in the parentheses first." And when he was finished, he said, "On one side of the fence will reside those who are good at math. And on the other will remain those who are bad at math, and woe unto them, for they shall weep and gnash their teeth." (Buerk, 1985, p. 59)

> It is shocking to find how many people do not believe they can learn, and how many more believe learning to be difficult. (Herbert, 1965, p. 64)

The majority of research in gender and mathematics, examined in chapter 2, begins with the "fact" that women do not participate in mathematics to the degree that men do, and with the assumption that women do not achieve at the same level in mathematics as men do. For the most part, research that begins in this place has confirmed the inferior status, however it is defined, of women's participation and attainment in mathematics. But if we alter our assumptions and our initial questions, we will reach conclusions that will be very different.

First generation research seeks to explain and ultimately to alter women's decisions to avoid mathematics because the researchers assume that women in fact avoid mathematics. This assumption is based in a male-centered definition of mathematics that recognizes the mathematical aspect of activity only if the majority of people engaging in that activity are men. In other words, occupations like engineering and medicine are seen as mathematical because, in addition to obvious mathematical content, the majority of engineers and physicians are men; if the majority of physicians were female, it is reasonable to suspect that the position would not be as highly regarded, nor seen as particularly mathematics-related. To understand this point, one need look no farther than the related field of nursing.

What these researchers have failed to see is the need for an explicit definition of what constitutes mathematical activity. All of the studies that have been cited so far have assumed that a common definition of mathematics exist and is shared by the researchers, the subjects of research, and the readers. It is particularly troubling that the central concept being investigated is not worthy of explicit definition. Possible definitions of mathematics, and the implications for women, will be explored in this chapter. Of specific interest is how the activities of women and men get defined as mathematical or not.

Most of the research in mathematics and gender has focused on the differences between females and males, but some attention has been given to how women learn and do mathematics. This is second generation research, which "embraces [women's] special qualities and rejects uncritical assimilation into the male world" (Noddings, 1990b, p. 393). Second generation work has its own benefits and problems, which will also be explored in this chapter. Before an examination of this research is conducted, it is imperative that the meaning(s) of mathematics be treated explicitly.

Meaning(s) of Mathematics

Philosophers of mathematics Philip Davis and Reuben Hersh (1981) begin *The Mathematical Experience* by defining mathematics as "the science of quantity and space," including the symbol systems, which they call a "naive definition, adequate for the dictionary and for an initial understanding" (p. 6). Near the end of the volume, having examined the foundations and history of mathematics, they redefine mathematics as "the study of mental objects with reproducible qualities" (p. 399). An alternative way to phrase this definition is that mathematics is the science of patterns involving quantity and/or space. All of these definitions are similar in that they emphasize the reproducibility of mathematical results, as well as its geometrical and numerical aspects.

For those interested in gender and mathematics, another defining feature of mathematics is its "male-centeredness."[1] Historically, most mathematicians have been men; while there have certainly been notable exceptions, it is more likely that someone could name ten famous male mathematicians than one female mathematician. As Spender (1993) notes:

> Even such ostensibly neutral subjects as math and science have assumed the centrality of the male; the examples relate to males, the illustrations take males as the standard, and while women have a splendid history of achievement as mathematicians, it would be possible for students to graduate from advanced mathematics classes without knowing that women ever participated, let alone excelled, in this area. (p. 44)

The common perception of mathematics as a male domain stems from the historic male dominance of the field, and educators interested in gender-equitable mathematics

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[1]It is also appropriate to understand mathematics in this sense as a European-centered activity. Although numerous contributions to mathematical knowledge have been made outside Europe, in the last several centuries those in the West have dominated mathematical activity.

education have focused considerable effort on eliminating this perception.

An alternative view of mathematics centers on the doing of mathematics, rather than on mathematical content or on the gender of those who engage in mathematical activity; rather than a masculine activity, mathematics in this view is a human endeavor. As a look to history confirms, those who do mathematics are found in all cultures and of both genders. Understanding mathematics in terms of doing mathematics represents a significant shift in the underlying philosophy of mathematics, and opens up many possibilities for the mathematics education of women.

If we base our definition of what mathematics is on how one engages in mathematical activity, then who engages in that activity becomes central. Further, by looking at different "doers" and groups of doers, we can make the case for multiple, perhaps contradictory, definitions of mathematics and mathematical knowledge. Exploring these possibilities for women is the focus of this chapter.

Social Constructivism and the Meaning of Mathematics

For centuries, mathematics has been dominated by the philosophy of absolutism which views mathematical knowledge as universal and infallible. But mathematicians and philosophers of mathematics are no longer able to sustain the myth of absolutism[2] primarily due to difficulties encountered in set theory (Davis & Hersh, 1981). Out of these difficulties have risen various forms of fallibilism, which hold that "mathematical truth is fallible and corrigible, and can never be regarded as beyond revision and correction" (P. Ernest, 1991, p. 18).

In the monograph *Constructivist Views on the Teaching and Learning of Mathematics*, Nel Noddings (1990a) examines the implications of constructivist philosophy on mathematics education. Constructivists must abandon the search for absolute truth and "recognize . . . the temporality of knowledge" (p. 12). But if all knowledge is construction, how can we determine which knowledge is valid and which is not?

> One of the first questions we ask when we are faced with an alleged knowledge claim is, "Who said that?" If [it] is a mathematical statement, we are more likely to accept it if George Polya or John von Neumann is its source than if, say, Ronald Reagan or a local high school student came up with it. The mathematicians have an authority that the other two do not have.
>
> But our judgement is not based on raw authority. The mathematicians' authority is not like that of the pope (or, at least, it shouldn't be). We do not accept their word simply because their office confers unassailable authority. Rather we accept [the mathematical statement], tentatively, because we know that mathematicians belong to a community that subjects all knowledge claims to careful scrutiny, and the criteria for such scrutiny are

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[2]For a complete exposition of the problems associated with absolutist philosophies, see P. Ernest, 1991, *The Philosophy of Mathematics Education*, London: Falmer.

> laid out for all the community to see. (pp. 11-12)

However, the result of construction may be errors that are not detected in the consideration process; indeed, there is always some skepticism over the completeness and correctness of a proof (Davis & Hersh, 1981). It is this doubt that fuels efforts to investigate questions in the field of interest, questions which lead to further constructions resulting in still more possible knowledge presented to the community.

In *The Philosophy of Mathematics Education*, Paul Ernest (1991) proposes a variation on this philosophy of mathematics, *social constructivism*. Rather than focussing only on the justification of mathematical knowledge, as absolutist philosophies do, social constructivism addresses the genesis of mathematical knowledge as well as its justification. By this admission, Ernest is able to link objective and subjective knowledge "in a cycle in which each contributes to the renewal of the other" (p. 43).

The distinction that Ernest draws between *objective knowledge* and *subjective knowledge* is key. Subjective knowledge is the knowledge of an individual; in regards to mathematics, subjective thought is the mathematical thought of an individual mathematician. Objective knowledge, rather than "true" or "real" in the absolutist sense, is knowledge which is socially accepted. The mathematical knowledge of an individual mathematician, subjective knowledge, can become objective knowledge through the process of publication, criticism, revision, and acceptance by the mathematics community. Through the process of education, objective mathematical knowledge -- theorems, proofs, procedures, and linguistic conventions -- may be internalized and therefore become the subjective knowledge of the learner. But defining objective knowledge as that which is socially accepted means that one forsakes any claims to unshakable truth, which makes mathematical knowledge fallible. Any knowledge currently accepted is subject to challenge, modification, or rejection at any time by the community, in this case, by mathematicians. (See Figure 1.)

At this point, a nonmathematical example may assist in understanding. Take the following statement: Columbus discovered America in 1492. For many people, this is a simple statement of fact. Christopher Columbus did locate and map land unknown in Europe at the time, it was subsequently called America, and it did happen in 1492. This is objective knowledge, agreed to by most in the public community. As a student in public school, this objective knowledge was given to me so that it would become part of my subjective knowledge. I was even taught a rhyme to help me remember it.

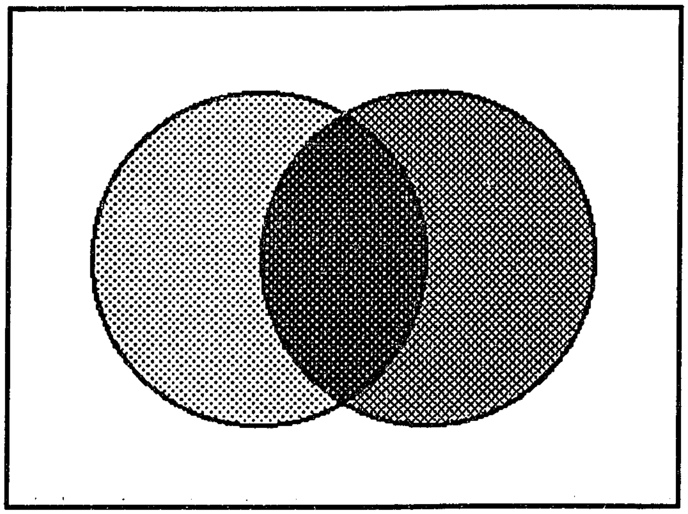

Figure 1. Venn diagram illustrating the relationship between objective knowledge and subjective knowledge described by P. Ernest (1991).

But recently, with the 500th anniversary of this "discovery," its general acceptance has been subjected to challenge from many sides. Some claim that other explorers came to the new world before Columbus, by perhaps as much as 2000 years. Others claim that no one could be credited with "discovering" this land other than the ancestors of the people living here before any explorers arrived. Still others, shocked and ashamed at the legacies of Columbus -- disease and slavery among other horrors -- choose to say that Columbus *invaded* America in 1492. Once widely accepted, the "fact" of Columbus's discovery is now in dispute.

Like historical knowledge, mathematical knowledge, rather than neutral and value-free as is commonly assumed, is "culture-bound, and imbued with the values of its makers and their cultural contexts" (P. Ernest, 1991, p. 261), in the process of construction. These cultural contexts have been, for the most part, those of European males, and the implications for women do not escape Ernest, who says:

> Underpinning the neutral view of mathematics is the cultural perspective and values that dominate Western scientific culture. This is the culture of rationality, which values reason but denigrates feeling. It separates knower from known, and objectifies its perceptions, removing the knowing subject from the universe of discourse. It is a discourse of separation and power, which seeks to subjugate nature and demands certainty and security from the knowledge it legitimates. It represents the aggressive masculine half of human nature, which

> has rejected the receptive and compassionate feminine half. Out of balance, it leads to assertions of power, ever more destructive armaments and conflicts, and the rape of the environment.
>
> The view of mathematics as male owned or as a joint social construction plays a central role in sustaining or challenging the male domination of Western culture. Success at dehumanized male mathematics may diminish our humanity, our ability to care, relate, and feel. Sustaining the inferiority of ethnic minority groups and women through this view of mathematics does symbolic violence to all, and subtracts from our integrity as human beings. (p. 279)

But what Ernest calls mathematical knowledge is the rarified knowledge of mathematicians. He notes that the identification of mathematics with masculinity and power is a "deeply entrenched cultural discourse" (p. 278) that explains the underparticipation of women (rather than inability, or lack of individual knowledge of the value of mathematics). However, earlier in *The Philosophy of Mathematics Education* (1991) Ernest development of the definitions of objective and subjective knowledge is itself fixed on the traditional, male-centered view of mathematics that he later critiques; that this fixation is a limited and limiting view of mathematics goes unrecognized.

The view of mathematical knowledge as that which is socially accepted allows for the possibility, albeit unexplored, of defining mathematical knowledge and mathematics in different ways. One such different way is to begin with the question, What mathematics is accepted, valued, and known by women?

Women's Ways of Knowing and Mathematics

In *Women's Ways of Knowing: The Development of Self, Voice, and Mind*, authors Belenky, Clinchy, Goldberger and Tarule (1986) "describe the ways of knowing that women have cultivated and learned to value" (p. x). Although the five types of women presented, *silent*, *receiving knowers*, *subjective knowers*, *procedural knowers*, and *constructing knowers*,[3] are developed in the broad context of knowing, they are applicable to understanding the ways that women (may) approach knowing in mathematics.

For women who are silent, there is no understanding, nor any hope of seeking to understand knowledge. Authorities present "that which is known" to non-authorities, who must accept it. "If authorities do tell you *what* is right, they never tell you *why* it is right. Authorities bellow but do not explain" (Belenky, et al., 1986, p. 28). For the silent, blind obedience to authority is the key to keeping out of trouble, to surviving. The silent women in the study had little

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[3]I have changed two of these terms slightly from the use in the text: from "receiv*ed* knowers" and "construct*ed* knowers" to "receiv*ing* knowers" and "construct*ing* knowers." The sense of action that my usage implies seems more consistent with the sense of action in the other terms, as well as with the sense of action on the part of the women that is conveyed in the descriptions.

formal education, or else found school to be a place of failure. "The silent women . . . were lost in the sea of words and numbers that flooded their schools. . . . For them the experience of school only confirmed their fears of being 'deaf and dumb'" (p. 34).

Unable to hear the "inner voice," silent women submit unquestioningly to the voice of authority. Cut off from all sources of intelligence, both internal and external, these women see themselves as utterly dependent on others. This dependence contributes to an extreme compliance with gender stereotypes; women are passive, incompetent.

Although the focus of this study is on knowing, writ broadly, the insights gained may be legitimately narrowed to mathematical knowing. Female students who are mathematically silent are totally disconnected from the intellectual experience of mathematical understanding. They obey the voice of the teacher, and carry the one into the next column. It is unnecessary to ask why, simple obedience is all that is required or tolerated. Many of the silent women in the study suffered physical abuse from men. How many girls sit silently in math class as a result of psychic abuse, possibly unintentional, from the teacher, utterly dependent, the "dumbest one of all"? (p. 29).[4]

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[4]Having critiqued mainstream research for "blaming the teacher," probably herself a victim of mathematics education, for perpetuating gender differences, it is

In contrast to the silent, receiving knowers are able to hear the voices of others. Whereas silent knowers want to be shown how to do something, receiving knowers are able to ask those in authority how to do something, or at least listen to them when they explained. Still, like the silent women, the receiving women could not imagine themselves as generators of knowledge, only as receivers, and perhaps as transmitters. When asked where authorities get their information, receiving knowers typically refer to a higher authority, unable to realize that others have the ability to construct knowledge for themselves.

In the mathematics classroom, the receiving knower looks forever to the teacher, or perhaps another student, for the procedure to follow. Unable to see any ability in herself to create a procedure, the receiving knower feels betrayed when the teacher asks her to go beyond that which is taught. It is likely that many girls are receiving knowers of mathematics, a conclusion supported by the data which show higher levels of performance in computation for girls than anything else, something which public school students are shown how to do carefully and repeatedly and upon which much emphasis is placed.

This way of knowing is characterized by dualism, viewing the world in polarities of right/wrong,

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disconcerting to find such a reference here. I ask the reader to be patient, and to trust that I will not leave the discussion at the current level.

black/white, we/they, good/bad, true/false. Such is the attitude taken towards mathematics in many classrooms. How many teachers of mathematics are themselves receiving knowers, able only to transmit knowledge given to them by authorities? Such teachers would be comfortable passing mathematical facts and procedures along to students; the "right/wrong" aspect of mathematics would be the most appealing, useful, and emphasized, for such a teacher.[5]

The subjective knower is a woman who has shifted to a vision of truth as personal, private, and intuited. She has moved from dualism to multiplicity, a recognition that truth is not absolute and singular, but multiple, infinite. "Subjectivist women distrust logic, analysis, abstraction, and even language" (p. 71), which they see as the territory of men, remote experts, espousing singular truths. Many of these women in Belenky's study had experienced abuse or incest in the past, and evinced a deep distrust of men and male modes of knowing. Others, often from advantaged backgrounds, came to subjectivism by other routes, but all had ultimately come to distrust the opinions of distanced experts. Intuition, a way of knowing given primarily (and generally derisively) to women, the

[5]It is clear that such a teacher could, most likely unwittingly, do violence to a student who is totally incapable of connecting in the slightest with even this aspect of mathematics, who is silent.

"still small voice" (p. 54) provided truth equal in stature to the truths of experts.

In mathematics, the shift to subjectivism results in students who claim to know, but who cannot explain their knowing. When such students give incorrect answers, they are dissatisfied with or disinterested in the explanation of the correct answer. Such students give incorrect answers often, for they have generally had little or no guidance in the development of intuition. Knowing intuitively may be regarded highly among mathematicians (Davis & Hersh, 1981), but it is not generally so regarded by mathematics teachers in schools.

Alternatively, such students might well dismiss mathematics altogether, rejecting the authority of the teacher to dictate what is worth knowing. In between, other students may select from the mathematical smorgasbord those things which seem worthwhile, leaving the remainder. In particular, such female students could be drawn to the content of mathematics in elementary school, with its focus on utility, on "real life," but repulsed by the abstractions of higher mathematics. Young women who feel this way would probably opt out of mathematics in secondary school:

> If I read something, and if it agrees with my senses, then I believe it, I know it. If it doesn't, I'll say, "Well, you may be right but I can't corroborate that." For me, proof is usually a sensory one. If you say, "Water falls," yeah, I believe it because I've seen it

> happen. If you call it gravity, then I say, "Oh, is that what you call it?" (Belenky, et al., 1986, p. 75)

The procedural knowers described in this study were women busy acquiring and applying procedures for obtaining and communicating knowledge. Having recognized that merely having an opinion or gut feeling is insufficient to satisfy others, procedural knowers seek the accepted form of knowing. For many, this shift represented a diminishing of personal authority; the inner voice has become critical of itself. Because these women think before they speak, they speak in measured tones or not at all. But they are not passively silent, they are waiting and reasoning.

Belenky, et al. (1986) identify two types of procedural knowing, *separate* and *connected*. Separate knowers are concerned with how students must think in order to play the "academic game"; the purpose is justification. These women are concerned with knowledge, separated from the object of knowledge, and desiring mastery over it. Connected knowers, on the other hand, are concerned with understanding, and seek a personal acquaintance with the object of knowledge. Connected knowers seek to know how the other thinks, and the purpose is connection rather than justification.

The separate knower solves problems, proves theorems, memorizes axioms, follows the accepted form. While perhaps capable of excellent work, it is distanced from the knower, and from the truth. The authors relate one woman's attitude:

> Simone could tell a well-reasoned argument from a poorly reasoned one, but she remained suspicious of reason. "It's just rhetoric [logic]," she said. "It's just a game. It doesn't prove anything." The person who won the argument was the person with the greater rhetorical [logical] skill, not the person closer to the truth. (p. 110)

Separate knowing is characteristic of most upper-level courses in mathematics in secondary schools and in college and university undergraduate programs.

Connected knowing, in contrast to separate knowing, stems from believing rather than from doubting. Connected knowers seek to see the other not in their own terms but in the other's terms. Connected knowing promises to reveal truths that are personal, particular, and experiential; connected knowers must therefore connect to other people. Seeking knowledge in a connected mode demands relationships of trust with other people -- trustfulness that they will care for my ideas, and trustworthiness to care for their ideas. It is helpful for both separate and connected knowers to meet with others in groups, but, unlike separate knowers who need not know each other, connected knowers need to meet in groups with people they know and trust. However, both separate and connected knowing is procedural; in both cases, the aim is to learn how to know, how to think.

Where separate knowers focus on a discipline (learning to think like a mathematician), connected knowers focus on the thinking of a person.

Separate and connected knowers who are students of mathematics will seek others with whom to share ideas. Connected knowers, like separate knowers, will examine and criticize the work, but out of a desire to improve it, not tear it down or reveal its flaws. In studying the work of someone else, the connected knower of mathematics will seek to understand the mind at work, how it saw, what it thought. The separate knower of mathematics, on the other hand, will seek to master the process of justification, of proof, recognized in the field.

Of all the women interviewed, only a handful were constructing knowers. Unlike procedural knowers, who seek mastery of an accepted way of knowing which provides women with a sense of power and authority in "a man's world," constructing knowers "attempt to integrate knowledge that they felt intuitively was personally important with knowledge they had learned from others" (Belenky, et al., 1986, p. 134). Rather than seeing knowing as separate from themselves, these women recognize that all knowledge is constructed, and that the knower is intimately connected to that which is known.

Because knowledge is a construction of the person who knows, constructing knowers associate knowledge with the context of knowing. Theories are models that approximate experience, which is necessarily more complex; theories are not "truth."

> In science you don't really want to say that something's true. You realize that you're dealing with a model. Our models are always simpler than the real world. The real world is more complex than anything we can create. We're simplifying everything so that we can work with it, but the thing is really more complex. When you try to describe things, you're leaving the truth because you're oversimplifying. (Belenky, et al., 1986, p. 138)

The process of simplification, decisions about what to leave out, to gloss over, is bound to its context, spatially and temporally coupled to a specific moment and knower.

Clearly, the work of those insightful "geniuses," university mathematicians, is representative of constructed knowing. In a study by Dorothy Buerk (1985), participants at a mathematics colloquium stressed the creative side of mathematics, the part that requires intuitive judgement, as most descriptive of how mathematicians do mathematics. The formal aspects of mathematics, proofs and so on, were reserved for professional presentations, textbooks, and classrooms; they represent the way in which mathematicians present their work to the world. As constructing knowers, these mathematicians are able to hear the voice of intuition, to recognize that which is important, to see patterns and make connections. But equally important, these constructing knowers are able to draw upon the formal work of others, to use objective knowledge to inform, guide, and support intuition, and ultimately to couch personal subjective knowledge in professionally acceptable ways.

The descriptions of female knowers examined here contrast sharply with the words of Noddings (1990a) cited earlier:

> Our judgement [of truth] is not based on raw authority. . . . We do not accept [the mathematicians'] word simply because their office confers unassailable authority. Rather we accept [the mathematical statement], tentatively, because we know that mathematicians belong to a community that subjects all knowledge claims to careful scrutiny, and the criteria for such scrutiny are laid out for all the community to see. (pp. 11-12)

While for Noddings, a former teacher of mathematics, the simple acceptance of authority may be insufficient, for the silent or receiving knowers, simple acceptance is all that is demanded or accepted by authority; for these knowers, rejection of the authority of the mathematician is unthinkable. The position taken by Noddings renders these learners silent, even as it allows for their improper subjective construction of mathematical knowledge. Likewise, the complete rejection of authority *qua* authority by subjective knowers is obscured, and the integration of connected and separate knowing by constructing knowers is only hinted at by Noddings. This statement, presented as the alternative to rote learning, is made from the position of procedural knower.

For female students of mathematics, the work of Belenky, et al., (1986) is potentially empowering, for it provides avenues for knowing not acknowledged in typical first generation research. In traditional research, students either know or do not know mathematics; either they elect to pursue mathematics or they do not; they either like and value mathematics or they do not. The categories that developed out of this study, however, provide us with a more complex model of mathematical knowing than is currently available; knowing mathematics is not "either/or," as traditional models have led us to believe.

But even a more sophisticated understanding of how women approach mathematical knowing does not address what it is that women are coming to know. This requires a look at what constitutes mathematics, a fundamental question that has not yet been addressed satisfactorily.

Women's Knowing in Mathematics

Earlier, I used a Venn diagram to illustrate the relationship between subjective and objective knowledge in mathematics. In Figure 2, I have added a third set which represents the knowledge that is applicable to a particular branch of mathematics, perhaps combinatorics or topology. For the mathematician interested in this field, the knowledge in this new set is particularly important, although what lies outside the set is also vital as the mathematician seeks to construct new knowledge.

Thus far, drawing the diagrams has been relatively simple; the next step, however, is more difficult. How shall we represent the relationship between the sets of mathematical knowledge of different groups of knowers of mathematics? Figure 3 represents one way to relate the knowledge, both objective and subjective, of mathematicians to that of secondary and elementary school students respectively.[6] Because individuals who possess doctorates in mathematics clearly have greater subjective and objective knowledge than students in public schools, the outer ring encloses each of the other two; for the same reason, the set of knowledge of secondary school students encloses that of elementary school students.

It is not immediately clear, however that such a representation is an accurate depiction of the relationships. While the assumption that mathematicians possess more mathematical knowledge than secondary school students is acceptable, the assumption that the corresponding ring should completely enclose that of secondary school is not. Students at lower levels in mathematics learn many things which would not be

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[6]Of course, many other distinctions, showing the sets of knowledge of persons at various levels of education/understanding could be drawn. However, since this is given for illustrative purposes, I have elected to keep the diagrams as simple as possible.

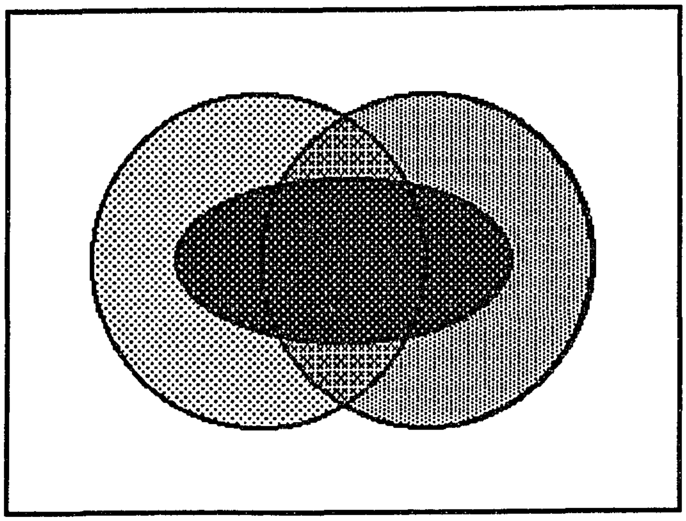

Figure 2. Venn diagram illustrating the relationship between objective knowledge, subjective knowledge, and knowledge in a particular area of mathematics.

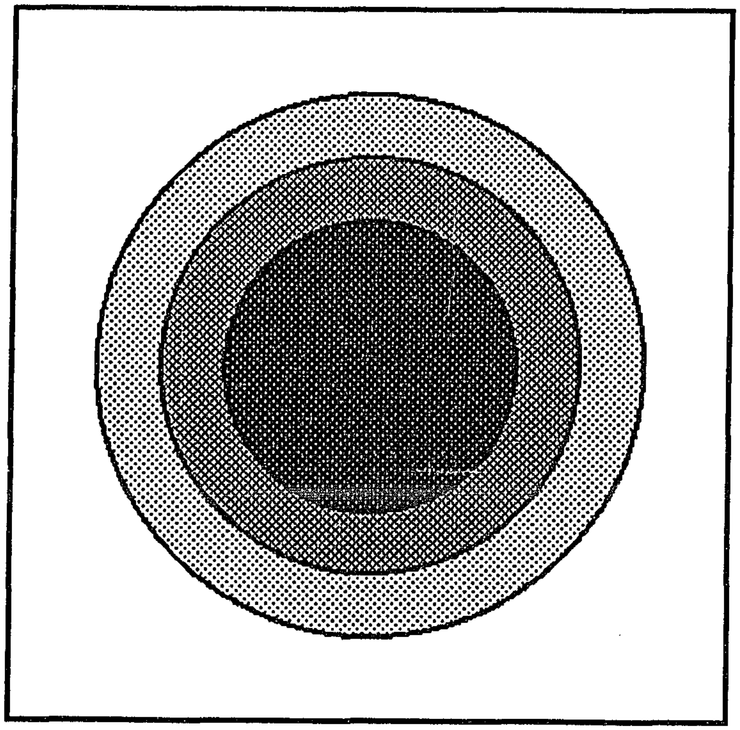

Figure 3. One way to show the relationship between the mathematical knowledge of mathematicians, secondary school students, and elementary school students.

considered "mathematical knowledge" by the community of mathematicians. An example of such knowledge is the conversion factor used to change inches to centimeters. This type of knowledge was probably once known by the mathematician, and since forgotten, or else now discounted as not "really" mathematics. Second, students are often taught things that, to the mathematician, are not really true, or that are true only in a certain sense of which the student is unaware. For example, students in algebra classes are commonly taught that a function is a set of ordered pairs where each value of x has one and only one corresponding y value, and that they can use a vertical line to test the graph of a relation to see if it is a function. (The relation is a function if the vertical line never intersects the graph in two points simultaneously.) But mathematicians know that this is the definition for "x as a function of y," which imposes narrower constraints than the term "function." Figure 4 illustrates the assumption that public school students possess mathematical knowledge that differs from that of the mathematician. However, students in early elementary school are often told that they should always subtract the smaller number from the larger. Since they have not yet encountered the concept of negativity, such teaching is consistent with the desired outcomes of problems given to these students. For the high school student, however,

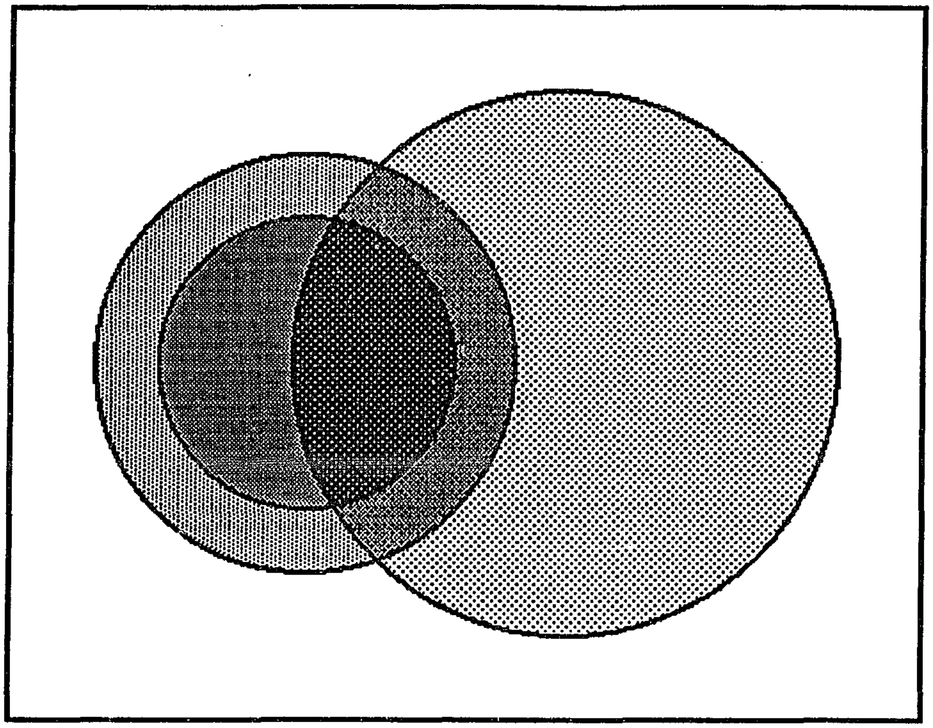

Figure 4. Another way to show the relationship between the mathematical knowledge of mathematicians, secondary school students, and elementary school students.

this simplistic approach to subtraction is often inappropriate for the situation. Therefore, Figure 5 illustrates the assumption that persons at each level possess knowledge that is not appropriately included at higher or lower levels.

At this point, it is necessary to reconsider this examination of the mathematical knowledge of different groups in light of the process by which mathematical knowledge become objective. For Paul Ernest (1991), mathematical knowledge is that of mathematicians; by expanding this discussion to other groups, I have implicitly defined other communities that accept certain knowledge as mathematical. In Figures 3, 4, and 5, these implicit communities consist of teachers, textbook authors, and curriculum planners, among others. What other communities might there be, and what "counts" as mathematical knowledge to them?

In these last three diagrams it is not the community of mathematicians that is the approving group, but a wider community; that is, mathematical knowledge in this sense is that which is known and accepted by most members of society. Many different diagrams could be drawn to illustrate the relationships between the mathematical knowledge held by members of various groups; depending on the groups selected, the amount and nature of the intersections would vary. Because acceptance of knowledge

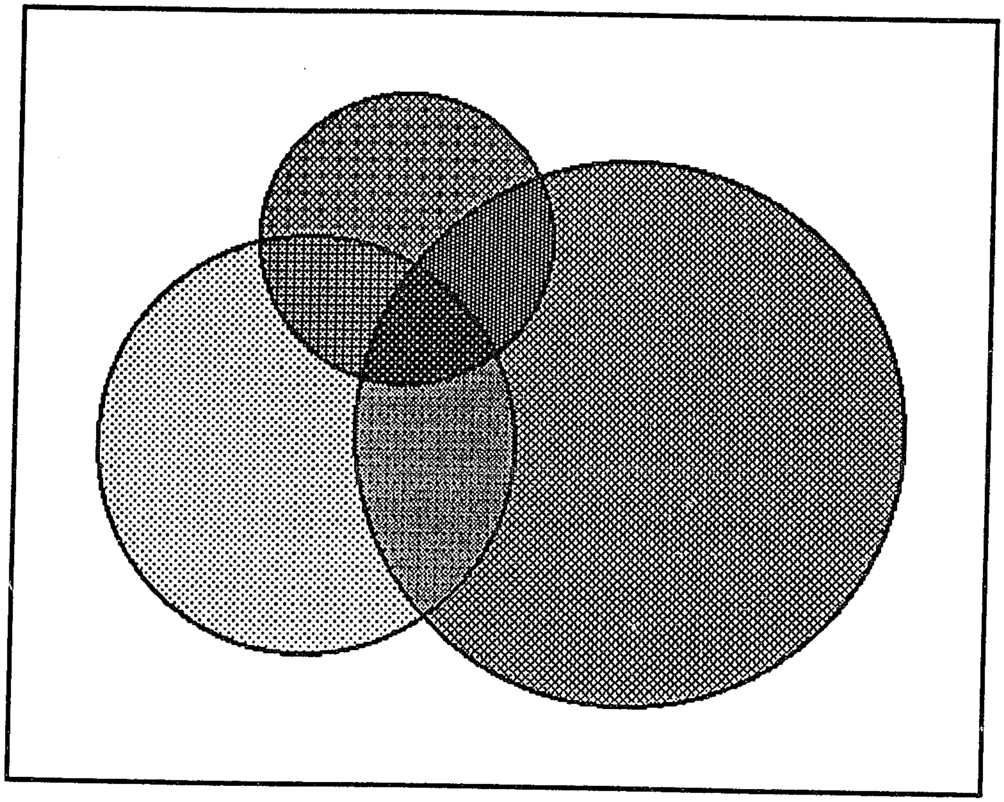

Figure 5. Still another way to show the relationship between the mathematical knowledge of mathematicians, secondary school students, and elementary school students.

by the social group defines the knowledge for that group, it follows that groups would have some mathematical knowledge that differed in some significant way(s) from that of other groups. For these other groups, some of the knowledge would be unknown, disregarded, or rejected, depending on the particularities of that group's relationship to mathematics and mathemticians. Because the mathematical participation of women as a cultural group differs from that of men as a cultural group, it is reasonable to assume that, in general, the mathematical knowledge of women differs in some ways from that of men.

Historically, mathematics has been something in which men have engaged. In addition to "pure" mathematics, disciplines such as physics, engineering, computer science, and medicine are generally regarded as mathematical, both because of the level of use of mathematical techniques and formulas and that these are things in which men dominate. But knowledge that certain activities are mathematical and others are not is socially constructed; like mathematical knowledge, it has its basis in the agreement of the community. It is my contention that the mathematical underpinnings of activities which are seen as "masculine" are recognized, but "feminine" activity is rarely given serious consideration for mathematical underpinnings.

Because the foundational assumption is that women are not mathematical, the mathematical underpinnings of female activity have gone unnoticed. Beginning with the assumption that many of the things which predominantly women do will have mathematical aspects allows us to see these mathematical aspects; failing to hold that assumption obscures them.

Something like hairdressing, which is largely done by and to women, is clearly not mathematical in a traditionally-understood sense. Aside from the obvious role of numbers in paying for services (which could make any occupation mathematical), mathematics and hairdressing are not related. But I will argue that hairdressing has mathematical aspects, in the sense that it requires a sophisticated understanding of space, and of movement in space. In short, hairdressing requires visuo-spatialization abilities that are unrecognized.

Some of the data on the relationship between spatialization and mathematical ability were presented in chapter 2. In general, the evidence has pointed to greater spatialization ability among males; females have tended to score lower on tests of visual spatialization than their male peers, which has been used to explain gender differences in mathematics. This line of research has been critiqued on the basis that the relationship between spatialization ability and mathematical achievement has not been firmly established, and it is not sufficient to explain observed discrepancies in mathematical performance.

For the moment, I am willing to accept the notion that spatialization ability is an important component of mathematical ability.[7] I am not willing, on the basis of contrived and abstracted test items, to accept the conclusion that women are not as capable as men in this area. The example of the hairdresser will show why.

Styling hair, especially changing from one style to another, is more than the mere cutting of individual hairs or even sections of hair. Each person's hair is different, and will respond differently to different treatments. A pageboy cut, for example, will not look the same with straight hair as it will with curly hair. Hair that possesses some natural curl will be straighter when it is long, as the additional weight pulls the hair down. When a stylist cuts a customer's hair, the hair is generally wet, which alters its behavior and appearance. Wet hair is flatter and straighter than dry hair.

In cutting a customer's hair, the stylist must be able to envision how the hair will look when it is

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[7]For the Greeks, mathematics *was* geometry, the study of space. In a more recent example, Benoit Mandelbrot, father of fractals, gained admission to the prestigious École Polytechnique in Paris by using his spatialization ability to answer correctly enough questions to pass the admissions examination for which he was woefully underprepared (Gleick, 1987).

finished and dry. In order to achieve the desired look, the hair is sectioned, and each section is cut in the manner necessary. Often, this means that sections of hair are pulled away from the scalp, directly down, up or at an angle. The ends of the section are then cut, and the line of cut may be perpendicular to the hair shaft, or at another angle. The manipulation of hair, comb, and scissors by the hairdresser is a three-dimensional, geometrical dance that results, one hopes, in the perfect haircut.

There is not reason to assume that the mathematical aspects of haircutting are necessarily obvious to the hairstylist at work in the salon. What is being addressed is the failure of academics interested in gender and mathematics to identify the mathematical underpinnings of non-male activities. Beginning with the assumption that women are not mathematical eliminates such "feminine" occupations invisible to the scutiny of researchers; this ommission contributes to the affirmation of the initial assumption.

The research of Jean Lave (1988) into the arithmetic practices of grocery shoppers and dieters also sheds light on women's ways of knowing and using mathematics. Although not specifically focused on women, only three of the 35 participants were men, so the insights gained are applicable here. The participants in the supermarket study were observed in the process of shopping and were given a variety of mathematical exercises in the home, including an arithmetic test[8] and a best-buy simulation.

In the grocery store, these shoppers performed at the average level of 98% accuracy, compared to the mean level of accuracy of 93% on the best-buy simulation and 59% on the arithmetic test. Lave credits this difference to the control that people feel in the supermarket, exercising options to define, re-define and abandon problems, over the lack of control experienced in the school-like environment of the arithmetic test. The complex mathematical knowledge displayed in the supermarket is connected to other knowledge, like what the family should or will eat, whereas a test of arithmetical knowledge calls for a display of separate knowledge, the ability to reproduce the procedures of the discipline correctly.

Intuition, Mathematics, and Women

In mathematics, connections between diverse fields are often first recognized through the intuitive sense of the mathematician (Davis & Hersh, 1981; P. Ernest, 1991). In physics, recognition of the ring structure of benzene by Friedrich August von Kekule was prompted by his dream

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[8]Although the researchers preferred to call this an "exercise," the "just plain folks" of the study referred to it as a test, and responded to it as if it were a test. This response on the part of the people taking the test prompted Lave to admit that that is what it became.

of a snake swallowing its own tail.[9] Philosopher of science Paul Feyerabend (1988) claims that no progress can be made in science "without a frequent dismissal of reason . . . [for] *even within* science reason cannot and should not be allowed to be comprehensive and it must often be overruled, or eliminated, in favour of other agencies" (p. 164), one of which is intuition.

Conventional wisdom has it that women have intuitive abilities different from, and perhaps superior to, those of men. Sometimes a complement, often raised to suggest that women have correspondingly inferior analytical abilities, this bit of conventional wisdom may offer a new window through which to consider the mathematical attainment, participation, and achievement of female learners.

While rejecting the notion that there is something directly related to biological gender that places limits on the ability of an individual or group to "be intuitive," I do wish to entertain the idea that, *due to dominant perceptions rooted in shared cultural*

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[9]Weisberg (1986) notes that the German word *Halbschlaf* used by Kekule, often translated as "dream," may also be translated as "reverie" or "doze," which "would mean that he was not really sleeping, but rather was lost in thought" (p. 32). Weisberg also makes much of Kekule's admonition that scientists not make their dreams known prior to working out via "wakened understanding." Although Weisberg is attempting to undermine the notion of intuition, he actually clarifies the importance of intuition in scientific thought.

understandings of "female intuitions," women enjoy a certain freedom to consider alternative ways of knowing. Although de-legitimated as "women's ways," these alternatives are acceptable in a variety of contexts.[10]

If so, this is a critical insight for researchers interested in the mathematical learning of female students in particular. As women, our intuition is something which the dominant culture has taught us to privilege in ourselves, and the perception of mathematics as "non-intuitive" (a false perception, based upon a misleading presentation of the field by mathematicians) may help to explain the overwhelming avoidance of mathematics that is characteristic of most learners, especially of females.

The idea of intuition has its roots in human prehistory. Valued highly in all cultures except the rational and scientific West (Noddings & Shore, 1984), the importance of intuition as a way of knowing in mathematics is currently enjoying increased interest. Philosophers of mathematics Philip Davis and Reuben Hersh (1981) note that all standard philosophies of mathematics "rely in an essential way on some notion of intuition" (p. 393) but that all fail to define intuition. Furthermore, when intuition *is* addressed directly, it is treated as

[10]The acceptability of intuitive knowing seems to increase as the context of knowing becomes more "feminine." For example, "mother's intuition" receives popular praise, as it supports a woman's connectedness to the family.

superfluous to the actual work of mathematics, a treatment to which Davis and Hersh object. As a way of knowing, the stature of intuition varies on a continuum of desirability; it may be a distraction to be avoided, or an aid to be cultivated, or a bit of both.

For absolutist philosophies, intuition is particularly troubling. In trying to maintain infallible foundations, absolutism cannot resolve the mystery of intuitive knowing; by concerning itself only with the justification of knowledge, absolutism is able to maintain the false impression that intuition is optional. In seeking to link genesis with justification, however, social constructivism moves intuition from the margins of the discourse to the center.

This centering of intuition as an indispensable way of generating subjective knowledge may have important implications for women's knowing in mathematics. Throughout history, there is evidence of a "distinct and persistent notion" of an intuitive mode of knowing that is specific to women (Noddings & Shore, 1984, p. 38). Although these authors are unwilling to take "feminine intuition" as more than superstition in the absence of no more evidence than unsubstantiated folklore and cultural stereotyping, the pervasiveness of the idea of women's special intuitive abilities makes it a fictional truth which has material effect in the world of real women

(Walkerdine, 1990). Biological, psychological or anthropological confirmation is not needed, for the continued cultural retelling of this truthful fiction makes it real, and thereby legitimates a way of knowing that is potentially powerful for women.

Affirming the role of intuition in mathematical knowing allows for the power of intuition to be tapped, which is particularly significant in the mathematics education of women. Devalued, mathematical intuition is not explored or encouraged in students; placing high value on the use and development of intuitive understanding provides a new avenue for women to enter into mathematical knowing. At present, intuitive knowing is neither explored nor encouraged in mathematics instruction, so students of mathematics have few if any opportunities to develop and expand their intuitive abilities. If intuition were given a more prominent and valued position within mathematics teaching and learning, the social fiction of women's special intuitive abilities could positively impact the level of women's participation in mathematics. By denying the place of intuition in mathematical knowing, mathematics educators perpetuate the fiction that mathematics is anti-intuitive and anti-female.

For the mathematician, intuitive knowing generates subjective certainty, the conviction that subjective knowledge is true, which forms the basis of both the valuing of intuition and suspicion of it, for it may be correct or incorrect. Although treated tentatively by the knower, intuitions are vested with the power of certainty that makes abandoning faulty intuitions difficult at times, which generates suspicion about all intuitions. This subjective certainty of the knower is balanced by the objective uncertainty of the community. The intuitive sense is convinced, but the community remains skeptical; the tension between certainty and uncertainty drives the attempt to prove or refute the knowledge that is intuited.

Throughout written history, the idea of intuition is strongly connected to the visual sense. From the Latin verb *intueri*, "to look at," intuition is mental seeing, looking with the "mind's eye." The strength of this connection between intuition and seeing is confirmed by historical accounts of intuition (Noddings & Shore, 1984) as well as common cultural references: the "flash" of intuition that "illuminates" and allows understanding.

But, for women, other sensory metaphors may be more important. In the interviews of Belenky, et al., (1986), the women were far more likely to use an aural metaphor to describe their knowing than a visual one. In sharp contrast to visual metaphors or "knowing as seeing," aural metaphors imply a closeness, a connection, an interaction between knower and known. Knowing with the "mind's eye" suggests a passive observation of that which is known, of distance, perspective, disconnection. In order to hear, one must come close and listen for the whisper of intuition.

Knowing in mathematics is strongly connected to the visual, to "seeing" as understanding or knowing. But the visual is separated, in contrast to the connectedness of the aural. For women, the perception of mathematical knowledge as separate from themselves, to be received from outside authorities, precludes the development of subjective knowing, of listening to the inner voice.

Continuing to use a visual metaphor exclusively for intuitive knowing places limits on the level of connection between knower and known. Coupling an aural metaphor with the visual one brings knower and known into closer proximity; one must be close in order to hear the voice of intuition. This sense of connection can be made even stronger, closer, and more connected by adding other sensory metaphors: "turning an idea over and over in the mind," "grasping a concept," or "smelling something fishy." Taken together, visual and aural metaphors of knowing in mathematics multiply the avenues for developing instruction in mathematics.

The practice of mathematicians as they do mathematics is closely associated with connection. Dorothy Buerk (1985) presented excerpts of Carol Gilligan's book, *In a*

Different Voice (1982), to participants in a colloquium of the mathematics department of Ithaca College, juxtaposing abstract, formal reasoning and thinking with concrete, informal reasoning and thinking. The consensus of the group was that the informal examples represented the way mathematicians do mathematics, while the formal examples represented the way mathematics is presented in school. "For many, especially many women, this unfortunate disparity takes the life out of mathematics and mathematics out of their lives" (p. 64).

Legitimating Intuition in Mathematics Education: Connected Teaching

Like knowers, teachers' styles range on a continuum between highly *separate* and deeply *connected*. Belenky, et al., (1986) contrast the metaphor of a "teacher-banker" of Paulo Freire (1971) with the idea of a teacher-midwife. Where the teacher-banker seeks to deposit the knowledge she holds into her students, the teacher-midwife "assists [students] in the emergence of consciousness" (Belenky, et al., 1986, p. 218), not thinking for them, but providing encouragement and the assistance of her own knowledge as students give birth to their own thoughts. For female students in mathematics, this difference is critical.

In the classroom, the banking-teacher uses a separate style. The content and structure of the lesson are well-developed, and the reasoning is airtight. Although students may be invited to disagree, to probe the facts or arguments presented, the teacher has composed them in advance, taking great care to prepare the best lesson possible. One student, asked to recount a "really powerful learning experience," recalled her first introductory science class from college. Belenky, et al., (1986) provide an example:

> The professor marched into the lecture hall, placed upon his desk a large jar filled with dried beans, and invited the students to guess how many beans the jar contained. After listening to an enthusiastic chorus of wildly inarticulate estimates the professor smiled a thin, dry smile, revealed the correct answer, and announced, "You have just learned an important lesson about science. Never trust the evidence of your own senses." (p. 191)

Separate teachers possess knowledge students do not, which they are charged with dispensing. In this case, the professor wished to motivate his students to value the scientific method and instrumentation over the evidence of the senses alone. The effect on the woman in the study, however, was an unending aversion to science: she dropped the course that day and never looked back.

The effect of separate teaching on female students is very often diminishing and humiliating. Separate teaching does not confirm the student's ability to know; the teacher is the authority. This renders students "dumb and dependent" (p. 193), looking forever to the teacher for knowledge. In time, the student will also become a knower, and will join the community of scholars, but only after she is no longer a student.

Belenky and colleagues note that separate teaching has particularly detrimental results for women in science, which can easily be extended to include mathematics. As a historically male discipline, college science courses are usually taught by men. In the introductory courses that many students take, the lectures consist of a "series of syllabine statements" (p. 215), a polished product that only a professor could create. The perception of the science professor as the giver of truth was so strong that one woman concluded that "science is not a creation of the human mind!" (p. 216).

In contrast, the midwife-teacher uses a connected mode that begins by recognizing and valuing the knowledge that the student already possesses and her capacity for learning new truths herself. The authors provide another example:

> The teacher came into class carrying a large cardboard cube. She placed it on the desk in front of her and asked the class what it was. They said it was a cube. She asked what a cube was, and they said a cube contained six equal square sides. She asked how they knew that this object contained six equal square sides. By looking at it, they said. "But how do you know?" the teacher asked again. She pointed to the side facing her, therefore invisible to the students; then she lifted the cube and pointed to the side that had been face down on the desk, and, therefore, also invisible. "We can't look at all six sides of a cube at once, can we? So we can't exactly *see* a cube. But you know it not just because you have eyes but because you

> have intelligence. You invent the sides you cannot see. You use your intelligence to create the 'truth' about cubes." (p. 192).

Like the science teacher above, this philosophy teacher planned to teach the students the skills of philosophical analysis, the tools of her trade, but she begins with the affirmation of the students' abilities to construct some truth. Where none of the students in the science classes possessed the desired knowledge, all the members of the philosophy class knew that the cube had six equal square sides. "Midwife-teachers help students deliver their words to the world, and they use their own knowledge to put the students into conversation with other voices -- past and present -- in the culture" (p. 219).

In separate classes, the flow of the discourse is unidirectional and linear, from the teacher to the students. In the terminology of Paul Ernest (1991), the aim is to infuse the objective knowledge the teacher holds into the subjective knowledge of the students. In connected classes, however, the flow is a cycle of confirmation-evocation-confirmation between the teacher-student and the students-teachers.[11] In this cycle, knowledge is possessed and gain by all participants

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[11]This terminology is used by Belenky and colleagues to emphasize that everyone in a connected class is a learner, although the teacher occupies a special role that carries both authority and responsibility. While all possess the power to understand and to learn, the teacher is *not* just another student.

in the process. Rather than seeking to ascertain what knowledge is missing or incorrect in the minds of students, the connected teacher begins with the belief that all students already possess important knowledge and ways of learning -- the teaching cycle is based on this valued, prior knowledge, and seeks to challenge and expand it.

Paul Ernest (1991) notes three levels of mathematical knowledge, formal, informal and social;[12] in the West, these are valued in decreasing order. In mathematics classes, as Buerk (1985) showed, it is the highly valued, separate formal level that dominates; informal activity occurs behind the scenes, never revealed to students. The activities of creation are necessarily informal, giving them lower status than the formal display.

As a social construct, this hierarchy is also subject to scrutiny and rejection by the community, proposed by Ernest. Social constructivism acknowledges all learners -- women and men -- as creators, each constructing subjective knowledge of mathematics through the process of posing and solving problems. Because the mathematical activity of all learners involves the posing and solving of problems, it is different from the activity of professional mathematicians only in that mathematicians

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[12]The level of the social, addressed above, is left unaddressed by Ernest, as if its meaning were universal.

are those who have obtained "the critical assent of the mathematical community [to] produce *bona fide* new mathematical knowledge" (P. Ernest, 1991, p. 283).

To create this kind of learning environment, the teacher must relinquish power over the answers, methods, and choice of content of the lesson and allow students to explore the landscape of mathematics, under the teacher's guidance and protection. Although the teacher may propose the initial situation, the definition of the problem and the development of the solution method will also involve student responsibility. This sharing of responsibility provides students with a connection to their learning that is not present in a situation where teachers, textbook authors and governmental bodies impose strict educational guidelines on learning.

In order for this problem posing and solving approach to function in a way that is empowering for women, however, free investigation must be linked to a fallibilist view of mathematics. This view de-centers the unique and correct answers so critical to absolutist philosophies and instead emphasizes that all students are mathematical knowledge creators, necessarily possessed of mathematical understanding and capable of creating more. In short, it is connected, and as such does not silence female (or male) learners of mathematics.

Conclusion

This chapter has focused on the importance of the definition of mathematics on the learning of women, and on how women may come to know mathematics in ways other than those that are currently legitimated. We have seen that the way in which mathematics is defined -- either as absolute, separate, and logical, or as fallible, connected and intuitive -- has profound consequences for both the form and content of mathematics teaching. This in turn has serious implications for female mathematics students.

The result of the dominance of absolutist understandings of mathematics is separate teaching and knowing. As Belenky, et al., (1986) demonstrate, this teaching mode has severe consequences for women as knowers, particularly in mathematics. But shifting to a more connected mode necessitates abandoning absolutism for fallibilism, and giving up claims to absolute certainty in mathematical knowing.

This shift in philosophy promises a truly empowering, emancipatory mathematics education for women. Developing specific pedagogy will require research that focuses on how women come to understand and use mathematics -- something we clearly do -- not in order to bring them to the same place as men, but to facilitate their development as knowing creators of mathematics, to help them see themselves as constructing knowers.

The classroom processes needed to assist women in moving from silence to construction can only be made clear through research grounded in the assumption that women, like men, can and do knowingly create mathematical knowledge. The direction and possibilities for such research are explored in chapter 5.

CHAPTER 5

GENDER STUDIES IN MATHEMATICS: WHERE DO WE GO FROM HERE?

> Feminist work in education is divided mainly into first and second generation thinking, and so far the two have not engaged in productive dialogue to construct . . . third generation thought. (Noddings, 1990, p. 407)

> Rather than mathematics *for* all, the outcome of centering the human activity of mathematics is mathematics *by* all. A "problem posing pedagogy . . . is proposed because it empowers *all* learners, not a deficient minority" (P. Ernest, 1991, p. 292)

> Chaos has taken a beating in these pathologically normal and rational times. ("Northern Exposure," July 5, 1993)

In the work of the first generation, researchers have sought answers to questions that center on the ways in which women differ from, and are inferior to, men. Conversely, researchers of the second generation have rejected female/male comparisons in favor of focussing on the special qualities of women. For the most part, research in mathematics education has parallelled that of education as a whole: the majority of research is first generation, with a smattering of second generation research. By and large, little third generation work has been attempted, work that seeks to synthesize the knowledge gained from the first and second generations

(Noddings, 1990b). The aim of this chapter is to point the way to the beginning of such a synthesis.

Thus far, I have recounted events of significance in the development of wide-spread interest into mathematics and gender. Beginning with the seminal work of Elizabeth Fennema, I traced the research findings of the first generation; this general history raised questions about the energy driving the work of these researchers and supporting their focus on classroom intervention to direct and control educational outcomes. In partial answer to this question, I then turned to the launch of Sputnik and the sweeping and lasting changes in social attitudes toward education and technological progress that it provoked. Having glimpsed the questionable and disturbing underpinnings of the first generation project, I sought in chapter 4 to explore the possibilities for women's knowing in mathematics that does not rely on a masculine norm. This project is clearly unfinished, for too little primary data has been gathered to lend needed strength to this project. However, it is not necessary, perhaps not wise, for such data to be gathered without considering the possible directions, applications, and implications of future research.

In addition to the need for a new research agenda, chapter 4 pointed to different ways of knowing, teaching, and learning mathematics; separate ways were shown to dominate mathematics classrooms, if not mathematical knowing. This chapter will begin exploring the implications for a mathematics curriculum of connected knowing and teaching. Linked to this will be the development of mathematical intuition, and the chapter will also suggest changes in teaching and in research that this shift in focus may entail.

Connected Teaching in the Mathematics Classroom

At present, separate teaching dominates the majority of mathematics classrooms. As the work of Belenky et al. (1986) shows, this style of teaching and the knowledge that it emphasizes has particularly damaging consequences for female students in the sciences, including mathematics. In recent statements on teaching, the National Council of Teachers of Mathematics (1989, 1991b, 1991d) has recommended a move from separate teaching toward connected teaching, replacing the image of the teacher as a banker to something more like that of the midwife. In a collection of presentation materials sent to mathematics educators, one transparency master stated:

> To reach the goal of developing mathematical power for all students requires the creation of a curriculum and an environment, in which teaching and learning are to occur, that are very different from much of current practice. [We need] elementary and secondary teachers who are more proficient in selecting mathematical tasks to engage students' interests and abilities; . . . orchestrating classroom discourse in ways that promote the investigation

> and growth of mathematical ideas; . . . seeking, and helping students seek, connections to previous and developing knowledge. (1991c, p. 1)

The midwife teacher knows she cannot give birth for her students; she uses her greater mathematical knowledge and past experiences to assist students in giving birth to mathematical ideas that are new to them.

But this will not necessarily transform students from procedural knowers to constructing knowers. Although NCTM does concede that students should pursue hunches and guesses, the "vision" of mathematics teaching presented in recent publications deals with nonrational ways of knowing implicitly rather than explicitly. In *Curriculum and Evaluation Standards for School Mathematics* (1989) four standards are common to all grades levels: Mathematics as Problem Solving; Mathematics as Reasoning, Mathematics as Communication; and Mathematical Connections. In the teaching and learning examples in this document (as well as in *Professional Standards for Teaching Mathematics* [NCTM, 1991]) drawing on, developing, and extending the *rational* powers of students are emphasized. Teachers present mathematical situations to capture or further students' interests and to increase their ability to make and evaluate conjectures, to solve problems using mathematical techniques and concepts, to make connections between mathematical ideas and to employ mathematical understandings in other disciplines, and to share information and ideas with others engaged in similar tasks.

The emphasis here is on learning mathematics through engaging in mathematical activity. Currently, most mathematics students are *passive* receivers of information (Carpenter, Corbitt, Kepner, Lindquist, & Reys, 1981; NCTM, 1991c); the new vision depicts students as *active* receivers of information. NCTM has attempted to make the shift to connected teaching, and has recognized the centrality of subjective knowing to doing mathematics. What they have failed to recognize is that constructing knowers, like mathematicians, are able to use their intuitive, nonrational abilities in addition to their powers of reason.

Intuition is a critical part of knowing constructively and may require that "analytic thinking [be] suspended or placed in a subservient role. Perhaps the right advice is to 'stop thinking' and 'just do' . . . with the intention and expectation of understanding" (Noddings & Shore, 1984, p. 83). Placing too much emphasis on reasoning in the classroom may deter the generation of intuitive modes; the whisper of intuition cannot be heard if we are attending to the voice of reason. Reaching the goals that NCTM has set requires cultivating intuition in mathematics, but developing intuition and intuitive modes of knowing requires taking steps that have not yet been endorsed.

The function of intuition that makes it necessary for reaching these goals is that of *experience enabler.* In the constructivist view, adopted by NCTM with respect to *rationality*, intuition precedes experience, makes experience possible, provides experience with direction and motivation, and allows for the constructing of knowledge from experience. "Without intuition, . . . experience would be something merely 'had,' not something anticipated, organized, chosen, evaluated" (Noddings & Shore, 1984). The description of experience devoid of intuition, as something merely "had," is chillingly similar to that of many mathematics classrooms; these reactions of students to mathematical learning experiences are similar to those depicted in the vision of NCTM. In order to achieve this in the classroom, cultivating intuitive modes of learning will be critical.

How can intuitive modes be cultivated in the classroom? Noddings and Shore provide a clue:

> The first and most obvious thing we can do to encourage intuitive activity is to acknowledge intuitive capacity and the reality of intuitive modes. As teachers we can share with our students information about intuitive activity, our own intuitive experiences, and biographical accounts of intuitive thinking that has produced admirable results. (p. 91)

We can discuss ways individuals and cultures have developed to enhance intuition, like listening to or playing music, fasting, meditating, or engaging in physical activity.[1] This treatment of intuition in the classroom should encourage students to experiment with ways to enhance intuition that are suitable to them and the development of specific practices designed to enhance intuitive modes. However, participation in enhancement activities must be voluntary and be conducted in a trusting relationship between teachers, students, and parents. Because of the intensely personal nature of intuitive engagement, it is particularly crucial that enhancement routines not signify membership in a particular group or acceptance of a particular set of beliefs.

Because attending to intuition requires a willing release of self, cultivating intuition in the classroom requires "securing the active participation of the student" (p. 123) not only in the construction of knowledge but also in constructing the purposes for knowing by engaging with students to consider why learning is important and desirable. It is necessary to heal the split in students between obedience and rebelliousness before intuition can flourish, to consider questions about why something is to be pursued before engaging in the

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[1]Noddings and Shore also advocate discussing the use of "mind altering substances" (p. 92) by various cultures and associated problems. This provides a basis for exploring the topic with students without resorting to moralizing or preaching.

pursuit. Instead of *ordered* to engage with, or at least endure, the presented material, students are *invited* to see, to understand, to explore, to hear. The rewards of such invitations to engage are well worth the care necessary to develop ways of inviting students to learn mathematics. However, there are ominous implications for classroom practice: In the extreme case, students may refuse engagement; more likely, and perhaps more frightening, the intuitive leaps generated by this engagement may take students in directions for which teachers are unprepared because such leaps are indeterminate. Cultivating intuitive modes of learning involves introducing disruptions in understanding, the disequilibrium that provokes students to engage. The results of such disruption are inherently unpredictable (Doll, 1993).

This unpredictable and therefore uncontrollable aspect of intuition has prevented explicit endorsement of intuition as a means of knowing mathematics. Coupled with the powerful image of mathematics as formal and rational in the didactic tradition, the dynamic nature of intuitive learning seems dangerously chaotic. But as Doll (1993) shows, far from being a destructive force, the self-organization that arises from perturbations of stability in the classroom drives learning. Rather than being set in advance, the goals, purposes and objectives of learning emerge from within action as action emerges from purpose. As direction emerges from engagement specific plans are conjointly determined by the teacher and the student. This requires flexibility in planning, and presents students the opportunity to come to a depth of understanding of subject matter, its history, structure and parameters, not obtainable through traditional teaching (Noddings & Shore, 1984).

This inability to predict accurately where subject matter investigations will lead is frightening as it requires that we relinquish the illusion of control over learning. While it is reasonable to assume that a rich environment for investigating mathematical topics will include a certain "core," exactly when and how that core will be addressed is unknown; indeed, certain aspects may not be addressed at all. In the case of something like the "basic facts" of arithmetic, it is difficult to believe that this knowledge will not be deemed necessary and valuable, and that a self-organizing curriculum that draws upon intuitive powers of understanding will not include this information, but we cannot guarantee that all students will always learn the multiplication tables in the third grade.[2]

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[2]Of course, this is not guaranteed by current practice either, but it is currently presumed to be a reachable and desirable goal by many.

Clearly, it is not the richness of the learning environment nor the depth of understanding made possible by a dynamic approach to curriculum and instruction that causes NCTM to shy away from openly advocating an emergent curriculum; the broad nature of the curriculum and evaluation vision that has been proposed (and warmly received) supports the notion of flexibility in setting initial goals. Although *Curriculum and Evaluation Standards for School Mathematics* embraces the idea that mathematical understanding is self-organizing and emergent, opposing the vision is the traditional notion of prediction and control.

Under the traditional vision, teachers select and sequence classroom experiences to facilitate engagement with certain ideas, possessing prior knowledge of what intuitions, ideas, and actions these experiences will elicit from students. Although encouraged to capitalize on the "teachable moment," that spark of insight that can lead students in divergent directions, teachers do not actively seek to provide the environment for divergence that can lead to generative chaos, but seek instead to present experiences that cause students' learning to center on the idea or skill to be mastered.

Direction is not the only aspect of this intuitive, emergent curriculum that is unpredictable and uncontrollable. The amount of time needed for knowing and understanding cannot be specified in advance of action. An emergent curriculum is not bound to linear notions of time; principles of recursion in dynamic systems suggest that ideas must be revisited again and again without end or beginning. Unlike repetition, with its focus on mastery of performance through drill, recursion is transformative reflection (Doll, 1993). Noddings & Shore (1984) provide an example showing the value of educational recursion worth quoting at length:

> A curriculum that takes intuition seriously must build a considerable redundancy (or what appears on the surface as redundancy), for the inner eye . . . delights in familiar scenes colored by the passage of time and the growth of perception.
>
> Even in mathematics, where things are inevitably built one on the other, we fail to incorporate the appropriate amount of repetition [recursion] in our instruction. We teach the usual multiplication algorithm, for example, in third or fourth grade. Everyone learns how to do the following:
>
> $$\begin{array}{r} 43 \\ \underline{\times\ 52} \end{array}$$
>
> Later we teach something called the "distributive property," but we rarely go back to our fourth grade problem and say, "Now let's try a different procedure on this. Instead of starting by saying '2 times 3 equals 6,' let's start at the upper left corner and say, '4 times 2 equals 8' or '4 times 5 equals 20.' Where shall we write the '8' or the '20'?" Then we invite our students to invent their own processes as in the following:
>
> $$\begin{array}{r} 43 \\ \underline{\times\ 52} \\ 2000 \\ 80 \\ 150 \\ \underline{6} \\ 2236 \end{array}$$

> There are, thus, both backward-looking and forward-looking aspects. . . . On the one hand, we must make strange territory familiar in order to find our way about in it; on the other hand, we must occasionally make the familiar strange in order to look upon it with renewed interest and insight. (pp. 140-141)

The actions that the teacher will take to encourage transformative reflection cannot be scripted in advance of classroom interactions; how, when, and why to revisit prior understandings emerges from the dynamic interactions between students, teachers, and mathematics.

This interplay of forces places the teacher at a crucial vertex in the network of the classroom: her role is both as teacher-of-students and as student-of-teachers. Although clearly purposeful, the actions of such a teacher can be aimed at propelling the mathematical understanding of students in specific directions, but the tentative nature of the agreement between the teacher and the students cannot support absolute demands for content acquisition. Research by teachers on how they can provide an environment for students that supports intuitive learning in a climate of curriculum guides and graduation examinations would begin to articulate a mathematics pedagogy respectful of multiple approaches to mathematics, teaching, and learning.

Research on Gender

In addition to exploring the development of mathematical intuition, research in mathematics education needs to explore women's knowing in mathematics more fully. Although the works of Belenky et al. (1986) and Lave (1988) are certainly suggestive, they are an insufficient basis for drawing conclusions. In both cases, the research subjects were adults, not public school mathematics students; to understand better how women do or do not come to know mathematics it is important to listen to the voices of students still in public education as well as to those who are reflecting on their past school experiences.

Additionally, although a great deal of data have been collected on women's and men's knowing in mathematics as defined in schools, too little is known about nonstandard mathematical knowledge. In chapter 4, I argued that mathematics can have multiple meanings and domains of knowledge; research into differences and similarities between definitions and understandings of various groups, including women and men, will serve to enrich our understanding of what makes something "mathematical." It will also enrich our understanding of the relationship of gender to mathematical knowing.

It is important, too, to look beyond women's ways of knowing mathematics in schools to *students'* ways of knowing mathematics. This does not imply a retreat to the male-as-norm position of first generation feminism, nor should it necessarily evoke images of comparative studies. Instead the aim is to extend our understanding of how mathematics is known and how mathematics is done within classrooms as well as outside them. The focus need not be on altering patterns of participation, but on learning to recognize and value mathematical knowing in its multiple guises.

Such a research agenda presupposes that all students, indeed all people, possess mathematical ability, but that this ability will manifest itself in different ways for different students as well as in different ways for the same student at different times. The goal of research is to provide a basis on which to build methods of teaching that facilitate the growth of mathematical understanding and willingness to engage in mathematical activity, understood in broad, perhaps divergent, ways.

Although most of the research cited thus far has concentrated on gender differences in learning and pursuing mathematics, the significance of such differences are dubious. As Walden and Walkerdine (1990) argue, what is referred to as significance is usually based on some statistical test of significance. The use of the term significance gives these results "a legitimacy that can be over-rated" (p. 123) and makes the magnitude of the differences that can be detected seem larger than the data support.

In the report of the results from the second National Assessment of Educational Progress (Carpenter, et al., 1981), concern was expressed over the finding that the majority of high school students take only two years of mathematics, and the authors reported "less difference in male and female enrollment in mathematics classes than might have been predicted from earlier studies" (p. 149). This raises questions about *male* underparticipation and underachievement in mathematics, factors hidden by the research focus of the first and of the second generation.

Beyond Gender

The concerns and efforts of first generation researchers notwithstanding, there are strong indications in the literature that concerns about gender differences in mathematics learning are misplaced, and that the effort now being expended to discover the "truth" about gender and to design and implement interventions to retain female mathematics students should be redirected toward improving the mathematics education of all students. To support such a claim, researchers compare the magnitude of within-group variation to that of between-group variation. Bleier (1984) comments:

> Whatever characteristic is measured, the range of variation is far greater *among* males or *among*

> females than *between* the two sexes. There is, in fact, far greater scientific and perhaps social justification for exploring and trying to understand the vast variance among individuals than the elusive, tiny variances between the sexes that elicit far greater attention and expenditure of resources than they merit. (p. 109)

In a comparison of the effects of grade and gender on mathematical attitude, Eccles, et al. (1985) found that grade effects were both more numerous and stronger than gender effects, and that attitude is negatively affected by the amount of time spent in school. Although this study did find that gender has an impact on mathematical attitude, and thereby on participation, the impact of positive/negative reinforcement via grades was much greater.

In an analysis of recipients of bachelor's degrees from 1971 to 1976, Chipman and Thomas (1985) found that women received roughly 40% of all bachelor's degrees in mathematics; in the same period, women received, on average, 44% of all bachelor's degrees. However, in 1975, less than 2% of all bachelor's degrees awarded were received in mathematics or statistics. Although the difference between women and men may be statistically significant in this case, the difference between the number of students pursuing college degrees and the number pursuing them in mathematics is "significantly more significant" than the gender difference.

Furthermore, Chipman and Thomas found that all professional and vocational degree programs reflect greater gender segregation than do liberal arts programs, not merely "mathematics-related" programs. They conjectured that, where students in a professional or vocational program are looking toward some specific occupation, students in liberal arts programs choose their majors out of a deep love of subject rather than its perceived utility. This conjecture, coupled with the dismally low percentage of college mathematics graduates, suggests that, in general, neither women nor men graduate from high school and enter college with a deep love of mathematics.

In 1976, John Ernest found gender differences in course-taking behavior but did not find gender differences in attitude towards mathematics. If students of both genders dislike mathematics to roughly the same degree, why are males more likely to pursue professional or vocational programs that draw heavily on mathematical ability? Sheila Tobias (1978) attempted to answer this question by taking into account the similarity of attitudes expressed by students of mathematics and gender differences in course-taking: "Men are not free to avoid math; women are" (p. 70). Although men may hate mathematics, Tobias suggests that since men occupy (at least in popular consciousness if not in fact) the cultural position of "breadwinner," this denies them the option of avoiding mathematics.[3] Because a man will be expected to "provide for the family," and because mathematics-related occupations are generally among the more lucrative options, cultural rather than intellectual or affective forces may direct men toward mathematics in greater numbers.

Although the research of the first generation has been critiqued often, it is perhaps not without merit entirely. In chapter 4, I averred that the way in which mathematics is defined is central in understanding the mathematical abilities of women; I also maintained that women engage in activity that is not seen as mathematical. It seems reasonable then to assume that men also engage in unrecognized mathematical activity which may or may not differ from that in which women engage in significant ways. If the goal is to increase the mathematical power of all students, not just of women, research must look at the "nonstandard" mathematical activities of men as well as that of other groups. The position of NCTM (1991d) is clear:

> By "every child" we mean specifically students who have been denied access in any way to educational opportunities as well as those who have not; students who are African American, Hispanic, American Indian, and other minorities

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[3]Another example of how fictions about male and female can function in truth in the lives of men and women (Walkerdine, 1990).

> as well as those who are considered to be part of the majority; students who are female as well as those who are male; students who have not been successful in school and in mathematics as well as those who have been successful. (p. 4)

If this goal is to be attained, then research which investigates the ways in which all students and groups of students come to know and use mathematics is needed.

To be inclusive, such research must also look beyond the standard categories of race, class, and gender which, even taken together, cannot describe the complexity of students' social positioning. To increase the resolution of the picture, different cultural, regional, geographical understandings of mathematics need to be investigated. Unlike the difference research of the first generation, the rationale for this research is not primarily comparative but exploratory, not to privilege certain views over others, but to enrich the understanding of all by validating the contributions and abilities of each. Such research will not form hierarchies by implying that the understandings of one group be shaped to conform to those of another group.

Central to this research agenda is the acknowledgement that mathematics is defined in different ways by different groups. For mathematicians, teachers, students, women, and men, the concept of mathematics holds different, if overlapping, meanings. What counts as "mathematical" must be constantly challenged in research and in schools if these multiple meanings are to be revealed. But this type of research cannot look only at the activities of women.

Out of this comes the central question for future research on women's and men's learning in mathematics: "How can we teach mathematics . . . more effectively to everyone?" (Chipman & Thomas, 1985, p. 23). Although studies characteristic of both the first and second generations will be necessary to develop answers to this question, the aim goes beyond those of either generation. Focussing on the ways in which students do and do not know mathematics, both in comparison and in isolation, in general as well as in particular, will provide critical insights into ways to improve learning, knowing, and teaching in mathematics for all students.

Beginning Again

For as long as I can remember, I have been attracted to mathematics. My interest in mathematics was fed by my father from an early age; all my scholastic pursuits were constantly and consistently praised and supported by my mother. Together my parents gave me a determination to realize my educational goals and an affinity toward mathematics. At the time I associated my father with mathematics and my mother with reading, but such an association no longer seems valid, suggesting as it does that my father was mathematical and my mother was not.

It is certainly true that my father possesses greater computational proficiency than my mother. I remember my parents sitting at the kitchen table sorting through the monthly bills and reconciling the bank statement with the checkbook records. My father held the register of checks, adding deposits and subtracting withdrawals to determine the balance as my mother sorted and stacked checks and bills. But the overt mathematical abilities displayed by my father should not suggest that my mother did not have equal, perhaps superior, mathematical abilities; these abilities, however, were not computational and therefore are not as readily recognized as mathematical.

Although my father was responsible for the computations necessary for reconciling the bank statement, my mother was (and is) responsible for determining how the family's financial resources were allocated. She was responsible for budgeting and spending, at which she excelled. My father sees no further than the amount of cash in his wallet; my mother made certain the monthly income lasted the entire month. I remember the lecture she gave me when my first check was returned for insufficient funds, which included a story about the time she was left with less than one dollar in the checking account. Although her computational skills are not as good as those of my father, my mother has never bounced a check. Neither has my father, but I have never seen him write a check or carry the checkbook.

But the mathematical abilities of my mother are not limited to making monetary decisions. As I related in chapter 1, each summer I went to McNeese State University in Lake Charles, Louisiana for seven weeks. Everything that I needed had to be taken, with the exception of food, including bedding and bath linens, books and notebooks, clothes, laundry supplies, a bicycle. About a month before the end of school, my mother would begin collecting together all of the necessities of the summer, packing things into suitcases, boxes, and the laundry basket and trashcan that I would be using. A few days before departure, she began deciding how to arrange this assortment of oddly-shaped containers in the trunk of her car. Before anything was taken from the house to the car, my mother had a general idea of where to begin packing so that everything would fit.

On at least one occasion, thinking that he would help, my father began packing the car without consulting my mother. He began with some of the largest items, but left space between them that was too small to accommodate any other items. In this fashion, he (and I) carried boxes and bags into the garage and piled them into the trunk. On finding the trunk nearly full and only half the luggage in the car, my mother quickly took over. Her first move was to empty the trunk. Not only did the car hold all the luggage I was taking, there was sufficient room to include snacks and drinks for the trip, and a picnic lunch for along the way.

These abilities at relating objects in space are not limited to packing the car. Her deftness allows her to store many pots, pans, and other kitchen gadgets in little space; for example, she has carefully determined in which order to stack her collection of storage bowls so that they all fit neatly inside one another (and which are exactly alike in size and are interchangeable for stacking) and always stacks them in the best way. Additionally, the stacks she forms, unlike those of my father or myself, are always balanced and never tip over. Finally, the stacks are arranged in the cupboards so that items used most often at nearest to where they are usually used, and space that is difficult to access, like the back of each cupboard, is used to store things used least often.

Although she would almost certainly deny it, my mother is capable of intuitive mathematical thinking, perhaps more so than my father. This understanding is new to me -- I certainly never associated mathematics with my mother until beginning this search for my own place in the literature on women in mathematics. The search for my self and my voice, which became and still becomes this dissertation, is only beginning, but I know at last that I have found the path.

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VITA

Mary E. Reeves was born on September 3, 1964 at Barksdale Air Force Base in Bossier City, Louisiana, and has lived in Louisiana all her life. She attended public elementary and secondary schools in Bossier City, and graduated from high school in 1982. Following graduation, she attended Tulane University in New Orleans for one year and majored in computer engineering. At that time, she transferred to Louisiana State University in Shreveport and finally settled on secondary mathematics education.

After graduating from college, Ms. Reeves taught high school mathematics in Bossier Parish for one year while enrolled part-time in the doctoral extension program offered by LSU-S and Louisiana State University in Baton Rouge. In the fall of 1988, she moved to Baton Rouge and enrolled as a full-time graduate student. During the course of her graduate work, she became very interested in elementary school mathematics, and worked with elementary education faculty and students. In addition to interest in elementary teaching in mathematics, she also has a longstanding interest in gender differences in learning mathematics, which evolved into her dissertation.

During the year prior to completing the dissertation, Ms. Reeves worked as an Instructor at the Northwestern State University of Louisiana, where she taught

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

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Major Field: Education

Title of Dissertation: Mathematics and Gender: A General History of Recent Research and Common Perceptions

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